Utrecht University

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## *A case study on European and African land use changes and their effects on migratory meadow bird populations*

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**Supervisor: dr. ir. Kees Klein Goldewijk**
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**Bachelor's thesis**

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# Summary

Bird biodiversity has been in decline on both global and continental scale. Especially farmland bird population sizes have decreased tremendously, mainly due to intensification of agriculture and habitat loss. Many Western-European meadow birds are partially or fully migratory. This thesis aimed to investigate to what extent land use changes in breeding, non-breeding and year-round habitats influence population changes of Western-European meadow birds. A case study was carried out for the Black-tailed Godwit and Common Redshank. Land use types in 1980, 2000 and 2017 were compared in the breeding, non-breeding and resident habitats of both meadow birds. Additionally, land cover changes from 1992 and 2015 in the same areas were compared. Acreages of relevant land use and cover types were calculated to identify trends. The data was also mapped to identify where exactly these land use and cover changes took place. Overall, urbanization has played a major role in all habitat types of the meadow birds studied. In the breeding habitat, land use and cover changes most likely had a negative effect, as parts of the habitat changed into unsuitable land use and land cover types. In non-breeding habitats, the effects of land use and land cover is less clear. What can be said is that the changes in non-breeding habitats were more extreme. However, evidence of land use and land cover changes did not point in one direction. It is thus difficult to assess how the changes in non-breeding habitat affected populations.

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# 1. Introduction

## 1.1 Problem statement

It is estimated that the global bird population has decreased by between a quarter and a fifth relative to pre-agricultural times (Gaston et al., 2003). According to the United Nations (2020), biodiversity loss endangers sustainable development and global heritage. In the past year, it has become even more clear how reckless behaviour towards Life on Land can threaten the survival of human beings (United Nations, 2021). One of the primary drivers of species extinction is habitat loss. Accordingly, limiting the process of habitat loss in the coming years will be crucial for sustainable development (United Nations, 2020).

Similar to global trends, bird biodiversity is also decreasing in Europe, caused by habitat loss and changes in land use. The European farmland bird population has decreased to 40% of its size in 1980 (Brlík et al., 2021). Especially in the last 60 years, the European agricultural landscape has gone through radical changes, mainly because of the increase in monoculture and the usage of fertilisers (van Zanten et al., 2014). The negative impacts of agricultural intensification on farmland birds have been well studied. The main identified reasons for population declines are a decrease in suitable habitats, little food availability, earlier mowing and more intense livestock grazing (Ausden & Bolton, 2012). This knowledge is being put into practice by providing clear guidelines for agriculture, which can improve conservation efforts of farmland bird species (Oosterveld et al., 2014; Schlaich et al., 2015).

Many European farmland birds are migratory. Besides their breeding habitat, migratory birds can also be threatened by changes in landscape along their migration routes, illegal hunting and changes in their non-breeding habitat (Birdlife International, 2021-a). Generally, the focus of research is on changes in acreage and quality of the breeding habitat. Logically, the breeding habitat conditions are crucial for nest success, which directly influence population sizes. However, the influence of non-breeding habitat conditions on bird population changes are less studied. Previous research has suggested that increasing droughts and hunting play a role outside of Western Europe (Birdlife International, 2021-a). Southern Europe, Western Africa and the Sahel region have also likely been subject to land use changes in the past decades. This could further explain bird population dynamics, which is why it is useful to look further into land use changes of non-breeding habitats.

## 1.2 Aim and research question

The aim of this thesis is to investigate to what extent the circumstances in different migratory habitats influence population changes of Western-European meadow breeding birds. Land use changes in Europe and Africa will be studied to see if there is a relation with trends in bird populations. This research will be a case study of two meadow bird species: the Black-tailed Godwit and the Common Redshank. These species show distinctly different migratory patterns. Because of this, they may respond differently to land use changes in their different habitats. As a result, the following research question will be addressed: *What land use changes have occurred in the breeding, non-breeding and permanent-residential habitat of Western European meadow birds and how has this influenced their population changes?*

## 1.3 Meadow birds

In Western and North Western Europe, a total of 8 wader bird species are known to breed in lowland grasslands, namely the Black-tailed Godwit (*Limosa limosa*), Common Redshank (*Tringa totanus),* Eurasian Oystercatcher (*Haematopus ostralegus)*, Northern Lapwing (*Vanellus vanellus*), Dunlin (*Calidris alpina*), Ruff (*Philomachus pugnax*), Common Snipe (*Gallinago gallinago*) and Curlew (*Numenius arquata*) (Ausden & Bolton, 2012). Of these meadow birds, this study will focus on the former two.

The Black-tailed Godwit is a wader species that breeds in wet grasslands. The role of intensive agriculture on its population changes has very well been studied. As it nests on the ground, nesting success is very much threatened by early mowing and intensive livestock grazing (Ausden & Bolton, 2012; Birdlife International, 2021-b). European Black-tailed Godwits have a well-known distinct migration pattern, so that land use changes in the well-defined wintering habitat can be closely studied.

The Common Redshank is another wader species that breeds in similar wet grasslands. It is more widely distributed than the Black-tailed Godwit, however, faces similar threats (Birdlife International, 2016). Table 1 presents how conservation priorities are generally lower for the Common Redshank than for the Black-tailed Godwit. It can also be noted that conservation priorities differ considerably amongst different scales.

*Table 1. Conservation status of the studied birds (Birdlife International, 2016; Birdlife International, 2017; BirdLife International, 2015; van Kleunen et al., 2017)*

| | Black-tailed Godwit | Common Redshank |
|---|---|---|
| Global Red List (IUCN) | Near Threatened | Least Concern |
| European Red List | Vulnerable | Least Concern |
| National Bird Red List (The Netherlands) | Vulnerable | Vulnerable |

## 1.4 Social and scientific relevance

Generally, biodiversity is crucial from a scientific perspective, as it is the key to the functioning of an ecosystem (Gamfeldt et al, 2008). Bird biodiversity is carefully monitored by keeping track of Red Lists on global, continental and national levels (Birdlife International, 2015; van Kleunen et al, 2017; Birdlife International, 2021-a). This further shows that bird biodiversity is perceived as particularly valuable. Domestic bird species could even be seen as cultural heritage.

The results of this study could be useful in multiple ways. Firstly, the attention to non-breeding habitat may lead to more studies towards the non-breeding areas of other birds than the two meadow birds studied. If research is conducted on other birds, general patterns in winter habitat population dynamics may be further identified, as well as changes in migration patterns.

Lastly, the research could lead to a more global approach regarding bird biodiversity conservation. The focus of national organisations could shift from conservation only in their respective country to cooperation across borders. It may lead to the realisation that efforts in sustaining domestic bird populations may be much less effective if no attention is given to conservation in the wintering habitat. For example, this realisation could result in Dutch conservation efforts for the Black-tailed Godwit not only being focused on improving the Dutch agricultural landscape, but also on nature conservation in the Sahel region.

# 2. Theory and concepts

This research aims to relate two areas of research: anthropogenic land use and cover change on the one hand, biodiversity and ecology on the other. By shortly stating existing theories and concepts, these can be combined into the conceptual model that will be used as the fundamentals of this research.

## 2.1 The Anthropocene

Humans have altered the biosphere on a scale that is incomparable to any other species and more similar to the impacts of major geological processes such as climate change (Crutzen, 2006; Ellis, 2015). With the fundamental alterations that humans have made to ecosystems and natural processes, the idea of a new geological epoch, "the Anthropocene", was put forward (Crutzen, 2006). One critical way that the biosphere has been altered by humankind historically is by changing or completely replacing landscape structures (Ellis & Ramankutty, 2008; Ellis et al, 2010). Ecosystem engineering is an ecological concept in which a species, the engineer, structurally changes its environment, therefore not just adapting evolutionarily, but actually making the environment more fit for the species (Ellis, 2015). Other species in the environment can experience advantages or disadvantages from these changes. By changing the environment to its advantage, the ecosystem engineer species can construct its own niche (Ellis, 2015). Figure 1 shows a simplified model of the theory.

Ellis (2015) argues that humans are excellent ecosystem engineers. By altering the structure and quality of the environment, humans made the landscape more fit for agriculture and livestock keeping. This process was even further accelerated by the fact that humans are ultrasocial and cultural beings, so that following generations could inherit their ecosystem engineering techniques. This research will not go in much further detail about the causes of anthropogenic structural changes of the environment. The Anthropocene will mainly be used to portray the scale in which humans have caused changes in acreage and quality of certain landscapes. Figure 1 also shows a positive feedback loop, explaining why land use change seems to have accelerated throughout the Anthropocene.

Based on the central role of humans changing the landscape in the Anthropocene, Ellis et al. (2010) put forward a new approach in which biomes of the world were reclassified into *anthropogenic biomes*, or *anthromes*. It is the way humans use the land that is central in the classification. By using anthromes, anthropogenic landscape transformations can be more clearly identified than by only looking at land cover, which solely looks at the physical structure of the earth surface. This study will therefore analyse land use changes by means of land cover changes, land use changes and changes in anthromes, so that results of these different analyses can be compared. A list of the anthrome classes can be found in appendix A.I.

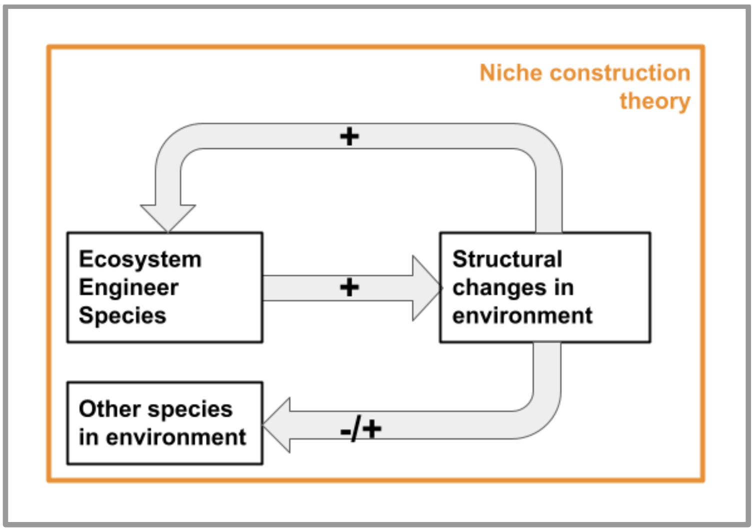



*Figure 1. Niche Construction Theory, adapted from Ellis (2015)*

## 2.2 Habitat selection theory

Fuller (2012) explains the factors that determine *habitat selection*, the process in which a species recognizes and chooses a habitat. Figure 2 shows a simple model of the habitat selection theory. Ultimate factors mostly show critical conditions to which a habitat must comply with for the species to use the habitat (Fuller, 2012). The proximate factors can give a further indication of the occurrence of a species. It must be mentioned that a loss of suitable habitat does not always immediately lead to the decrease of the total population, as it can also move to another habitat, increasing the density of the population in that area (Sutherland, 1998). This research focuses on changes in land use, which mostly influences the factors *Space* and *Structural and functional characteristics*.

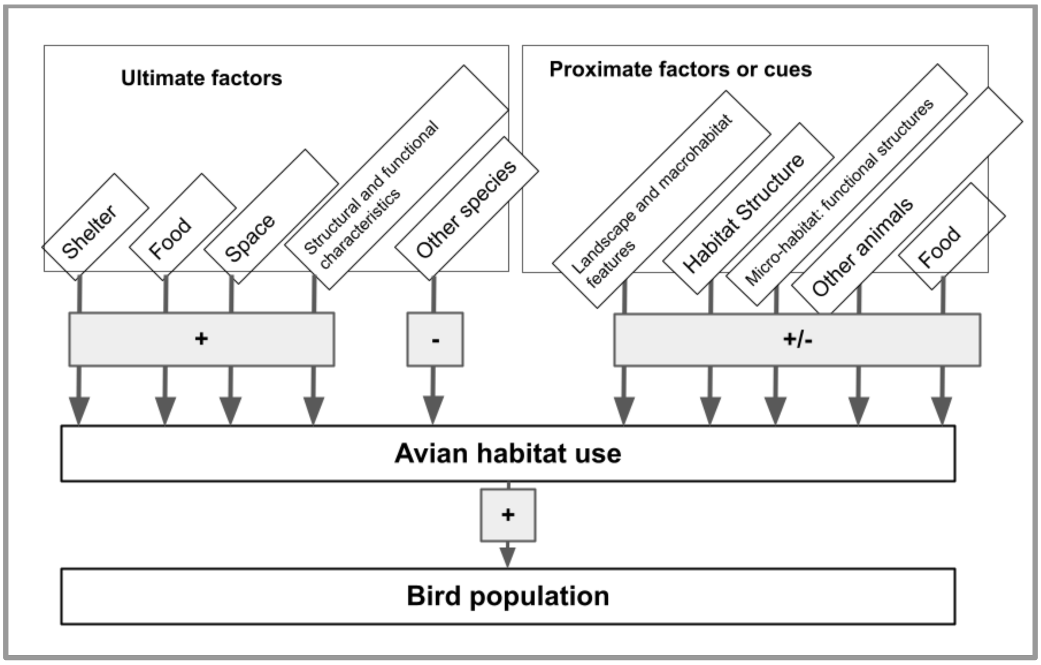



*Figure 2. Habitat selection theory, adapted from Fuller (2012)*

## 2.3 Bird migration theory

Migration complicates the *habitat selection theory* as mentioned above. Essentially, in the case of seasonally migratory birds, there is not only one habitat to monitor population dynamics in. It is therefore useful to distinguish the concepts of *population dynamics in season of reproduction* (breeding) and *season of survival* (non-breeding) (Alerstam & Hedenström, 1998). A loss in non-breeding habitat can result in the same loss in population as a loss in breeding habitat would (Sutherland, 1996).

The foremost reason for bird migration is the seasonal variation that occurs in most parts of our biosphere (Alerstam, 1993). Migratory birds move to more suitable habitats in (Northern Hemisphere) winter months, as breeding grounds are not fit for winter survival. They return in spring because the non-breeding habitat cannot be used for breeding; breeding habitat of migratory birds has different requirements (Alerstam, 1993; Alerstam & Hedenström, 1998).

In addition to the breeding and non-breeding habitats, migratory birds may also have a *resident habitat*. This can either indicate that part of the population is non-migratory, or that part of the population uses the habitat for the non-breeding season, while another uses it for breeding. This is the case for the Common Redshank. Part of the Western-European habitat is *resident habitat*. The Black-tailed Godwit, on the other hand, has a very small resident habitat as it is fully migratory.

It is clear that different migration patterns can be distinguished for different bird species. Specific migration patterns have mostly found their origins in evolutionary conditions (Alerstam & Hedenström, 1998). In *Chain migration* birds follow a similar latitudinal sequence: the most northern breeding populations also use the most northern winter survival habitat (Nilsson, 1858; cited in Alerstam & Hedenström, 1998). Contrarily, in the *Leap-frog migration* the most northern birds have to travel the furthest, to the most furthest survival area (Palmen, 1874; cited in Alerstam & Hedenström, 1998). The leap-frog migration is based on the assumption that the most southern breeding birds reach the closest survival habitat first, which results in more northern breeders having to pass these areas to find enough space (Alerstam, 1993).

Figure 3 presents the migration of the Black-tailed Godwit mostly resembling chain migration. Western European populations mostly travel along the coast of southern Europe to their non-breeding habitat in Morocco or south of the Sahara. Other Western-European Black-tailed Godwits migrate over Italy, and cross the Sahara at once. Icelandic populations may winter in Western Europe. The breeding habitat for European Black-tailed Godwit populations consists of lowland wet grasslands, herb-rich meadows, grassy marshlands, cattle pastures and hayfields. The non-breeding habitat requires flooded grasslands, irrigated rice fields or other freshwater habitats (BirdLife International, 2017).

The Common Redshank shows a distinct leapfrog migration pattern. Figure 3 shows that the species is mostly resident in Western Europe. Some breeding birds may move into the *resident* habitat during the non-breeding season, or move to the *non-breeding* habitats closest by. The most Northern birds, found in Northern Scandinavia, fly the furthest, all the way to West Africa. The Common Redshank has very similar breeding habitat requirements. It mostly breeds on inland wet grasslands, cultivated meadows and swampy heathlands. The non-breeding habitat is also similar, consisting of freshwater habitats, flooded grasslands and tidal mudflats. The main difference is that the Common Redshank does not make use of irrigated rice fields (BirdLife International, 2016).

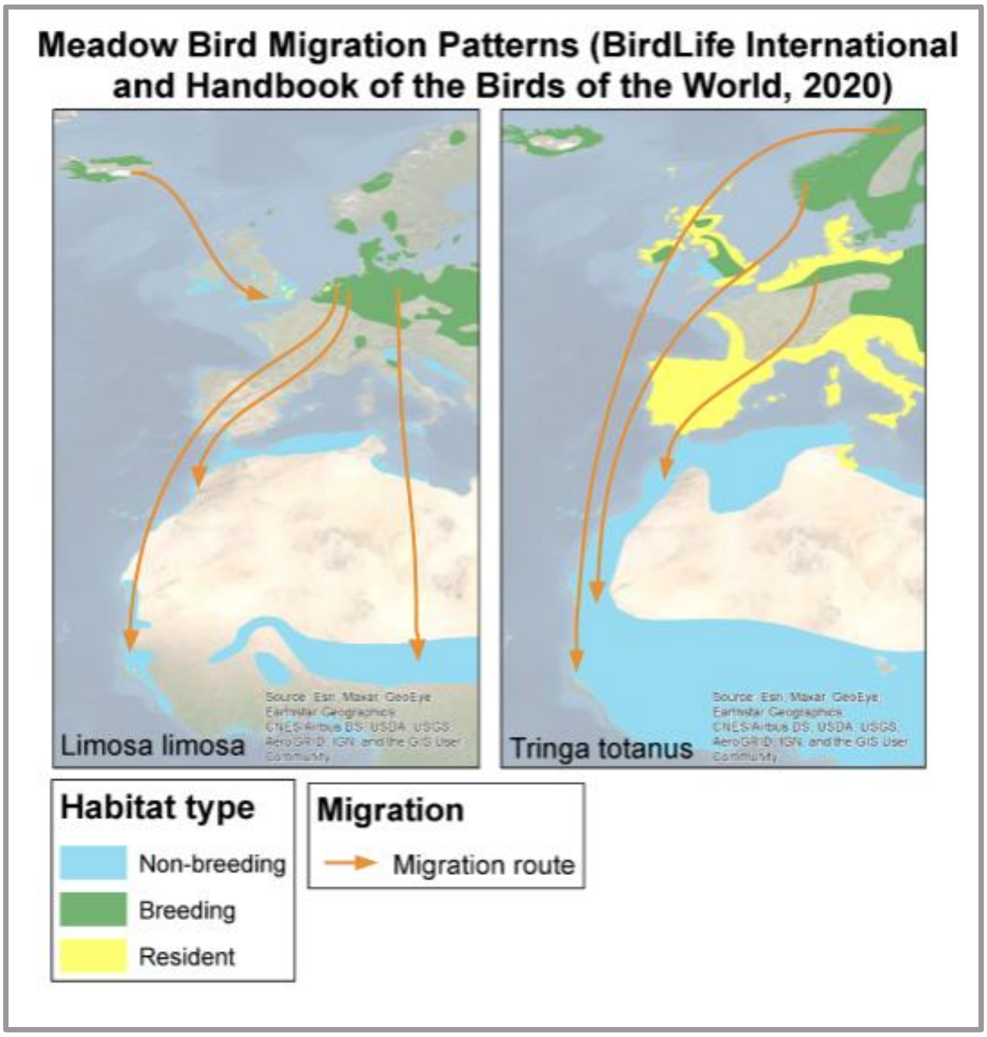



*Fig 3. Chain and leap-frog migration patterns and different habitats of the Black-tailed Godwit (Limosa limosa) and Common Redshank (Tringa totanus) (adapted from Birdlife International and Handbook of the Birds of the World, 2020).*

## 2.4 Conceptual model

Figure 4 shows the conceptual model. It shapes the different theories into an overview of the fundamentals that this study is based on. It suggests that structural landscape changes either in acreage or in quality can have a positive or negative effect on avian habitat selection. Structural landscape changes in the wintering habitat have an effect on wintering habitat use, while landscape changes in the breeding habitat have an effect on breeding habitat use. As the population size of these birds is dependent on both habitats, the influences on both local landscape changes of wintering and breeding area can affect the overall success of the bird species.

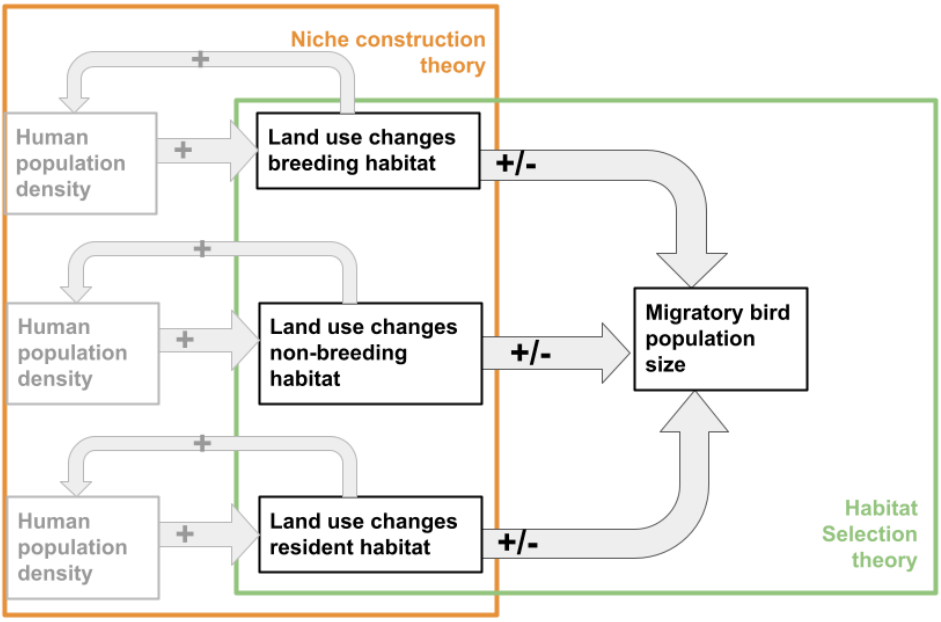



*Figure 4. Conceptual model of land use changes and bird biodiversity, adapted from Ellis (2015) and Fuller (2012).*

## 2.5 Analytical framework

As stated in the research aim, the proposed research focuses on the relation between *land use changes in the habitats of migratory birds* and *bird biodiversity*. To draw meaningful conclusions from this, changes in all habitats need to be studied. This way it can be well compared what influence certain habitats may have on population dynamics. The conceptual model above determines what concepts need to be measured to identify these effects. The study focuses on measuring the concepts within the *Habitat Selection theory* frame. Table 2 shows how these concepts will be measured in the breeding, non-breeding and resident habitat, for both the Black-tailed Godwit and the Common Redshank.

| Concept | Measurable variable | Categorization |
|---|---|---|
| Bird population size | Trend (relative to base year) | Relative number |
| Land use change (in breeding, non-breeding and resident habitat) | Anthrome changes | Percentage changes in acreage of certain land use types |
| | Land use changes: <br>- Grazing land | Change in km2 grazing land of total land area |
| Land cover change (in breeding, non-breeding and resident habitat) | Land cover changes | Percentage changes in acreage of certain land cover types |

*Table 2. Analytical framework.*

# 3. Research design and methods

The following section provides a detailed description of the data collection and data analysis of the study that were carried out to answer the research question.

## 3.1 Data collection

As outlined in the analytical framework, a substantial amount of data needed to be collected to carry out the project. This data was mostly collected from online databases.

### 3.1.1 Data on bird populations

The Pan-European Common Bird Monitoring Scheme holds data on 170 common European Birds (Brlík et al., 2021). For the Common Redshank, data on trends and indices from 1980 onwards was obtained, with 1980 being the base year for the trends. For the Black-tailed Godwit, the base year was 1984, thus for this species, data from 1984 was obtained.

Besides the European data, data on a national level was collected for both species, so that continental data could be compared to a more local scale. The database by Boele et al. (2021) contains Dutch breeding bird population size numbers. In this database, annual indices are available from 1984 to 2019, with trendlines from 1990 to 2019. Geographic or site-specific data on bird populations could not be accessed, because of long application request waiting times.

The breeding, non-breeding and resident habitats of the Black-tailed Godwit and the Common Redshank were provided by Birdlife International and the Handbook of the birds (2020). This geodatabase holds the species distribution of over 11,000 species for use in GIS. The distribution of the case study species was selected in GIS and a new layer was created for each breeding, non-breeding and resident habitat, so that the habitats could easily be used in further spatial analysis.

### 3.1.2 Anthrome data

The History Database of the Global Environment (HYDE), was used for geographic information on land use changes (Klein Goldewijk et al., 2017). For the anthrome raster data in this database, land use types are classified into the anthropogenic biomes (anthromes), as proposed by Ellis et al. (2010). Each anthrome raster grid cell holds a value that corresponds with a certain anthrome class. The anthrome classification can be found in Appendix A.I. For this study, anthrome maps at a resolution of 5 arc minutes of 1980, 2000 and 2017 were used.

### 3.1.3 Grazing land use data

To determine the amount of grazing land use, HYDE was used as well (Klein Goldewijk et al., 2017). In the grazing land use raster data, each grid cell holds a unique value, namely the total land used for grazing in this grid cell, in km2. Similar to the anthrome data, maps at a resolution of 5 arc minutes of 1980, 2000 and 2017 were obtained.

### 3.1.4 Data on land cover change

Land cover raster maps based on satellite imagery were collected from ESA (2017). Similar to the Anthrome raster maps, each grid cell of the land cover rasters holds a unique value that corresponds with a certain type of land cover. The list of land cover types can be found in the Appendix I.B. The land cover raster maps of the ESA are at a 300m resolution.

## 3.2 Data processing and analysis

### 3.2.1 Bird populations

Species trends were graphed from their base year onwards. Excel was used to create the graphs. The Pan-European Common Bird Monitoring Scheme by Brlík et al. (2021) also includes confidence levels for each bird species. This way, the upper and lower confidence levels could be used to create confidence bands.

### 3.2.2 Anthromes Changes

Several steps needed to be followed to process the data of anthromes in the different habitats. These steps are shown in Figure 5. First, the anthrome raster layer of a certain year and one type of habitat of one of the case study birds was loaded in Arcmap. The raster data was then clipped so that a raster layer only covering anthrome grid cells in the bird habitat was created. This was repeated for both case study birds, for each year and habitat type. Python commands were used for the clipping tool. For example, in the year 1980, in the breeding habitat of the Black-tailed Godwit, the following expression was used:

```
arcpy.Clip_management(in_raster="anthromes1980AD.asc",
rectangle="-180 -90 180,000000335276 83,6236001622702",
out_raster="<SAVE LOCATION>/anthromes1980LimosaB",
in_template_dataset="LimosaB", nodata_value="-9,999000e+03",
clipping_geometry="ClippingGeometry",
maintain_clipping_extent="NO_MAINTAIN_EXTENT")
```

Thus, 18 new anthrome raster layers were created this way. From these raster layers, maps were created to showcase the differences over time. Furthermore, for each of the raster layers, the total area per anthrome class needed to be calculated using the Zonal Statistics. Continuing with the example above, the Python command used to calculate the Zonal Statistics in the following way:

```
arcpy.gp.ZonalStatisticsAsTable_sa("anthromes1980LimosaB",
"Value", "anthromes1980LimosaB", "<SAVE
LOCATION>/tableanthromes2017LimosaB", "DATA", "MEAN")
```

The table that was created using this command, was copied into excel. From these excel tables, the AREA values of all Anthrome classes in the different habitats and years were structured into one table. This way, the Areas of different areas could be easily compared. Furthermore, the change between 1980 and 2017 of each Anthrome class in each habitat was calculated.

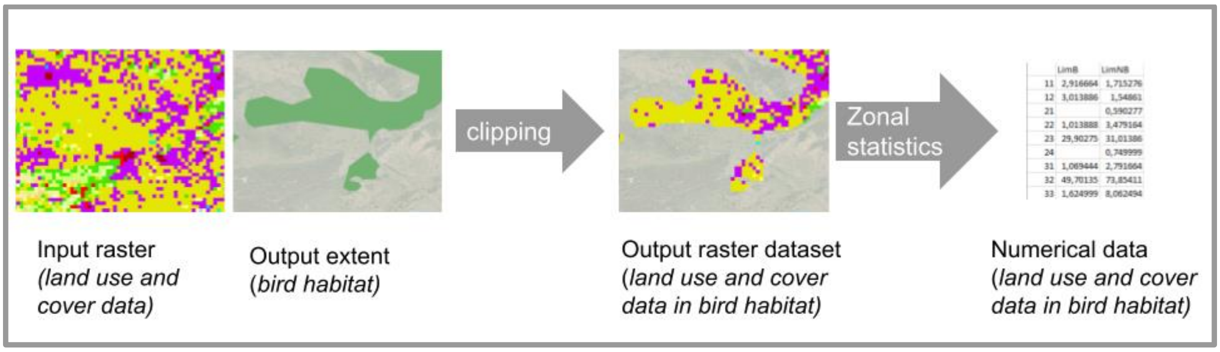



*Figure 5. obtaining land use and land cover data in bird habitat.*

### 3.2.3 Grazing Land Use Changes

In a similar way as for the Anthromes, the Grazing land use raster layers were clipped to create 18 raster layer maps, for both case study birds, all three habitats, in the years 1980, 2000, 2017. After these raster layers were created, the steps showcased in Figure 6 were followed. For each of the habitat types, the difference between 1980 and 2017 was calculated using the raster calculator. Again Python commands were used:

```
arcpy.gp.RasterCalculator_sa('"grazing2017LimosaB"-
"grazing1980LimosaB"', "<SAVE LOCATION>/grazingdiffLimosaB")
```

This way, a new raster layer was created, where each raster grid cell holds the difference between the 2017 value and the 1980 value. The created raster layer shows the change in km2, with a negative value indicating a decrease and a positive value indicating an increase. These raster layers were used to create maps so that geographic locations of increases or decreases can be easily identified. To do so, the stretched values were classified in classes of one standard deviation each.

The frequencies of these changes were also extracted and put into an Excel table. This data was used to create histograms for each habitat and each year. Histograms are useful in visualising data distributions. A histogram is a barred graph type that indicates the frequency of occurrence of certain data values. In this case, it indicates how many grid cells have had a similar change of grazing land use in km2. The histograms can further indicate whether the entire habitat type showed a similar change in grazing land use, or rather different.

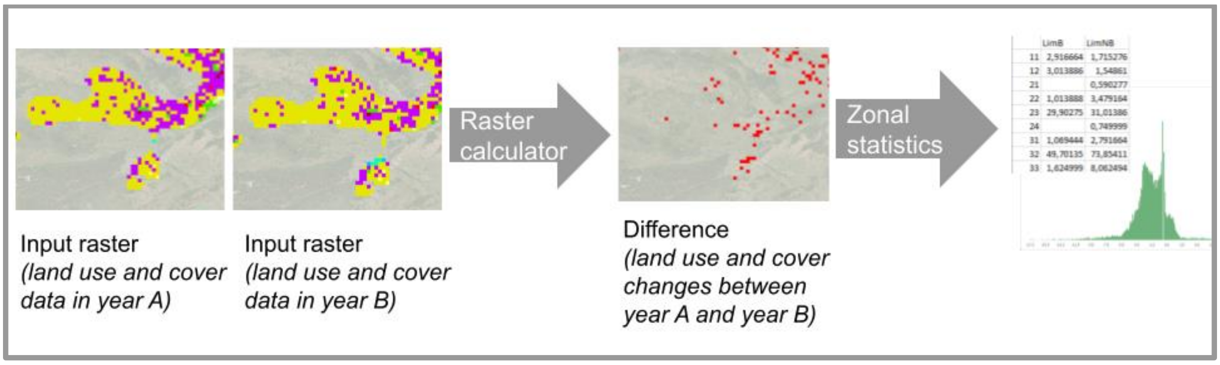



*Figure 6. calculating differences in land use and land cover over time.*

### 3.2.4 Land cover

To analyse the land cover changes in the three habitat types, similar steps to the Anthrome changes were followed (Figure 5). In this case, 12 raster layers were created by clipping the land cover raster layer for the years 1992 and 2015, to the clipping extent of the breeding, non-breeding and resident habitat type of both case study birds.

## 3.3 Ethics

This study used data on Red List bird species. The utmost care was taken in confirming that full consent of data-use was granted for all data of third parties. In messages requesting data from external databases, it was made very clear what data was required for the research and in what ways it would be used and/or published. Furthermore, data on bird species can be seen as sensitive information, as they are on the Red List and thus threatened. It is therefore important to remain cautious not to misinterpret data or results. To prevent this from happening, disclaimers on data use were thoroughly read and results were critically discussed. Lastly, close attention was paid to avoid plagiarism and/or fraud, by fully crediting all database sources and referencing all literature used in the research.

# 4. Results and analysis

## 4.1 Overview

Table 3 presents a concise summary of the results of the collected and analysed data. These results are further specified in their respective section below. Urbanisation has played a role in all habitat types of the bird species. In breeding habitats, agricultural lands are exchanged for urban areas. Meanwhile, in non-breeding habitats, agricultural lands and urban areas both increase, mostly at the cost of nature and bare areas. The resident habitat of the Black-tailed Godwit showed changes similar to the surrounding breeding habitat, where the habitat of the Common Redshank mostly was a midway between the breeding and non-breeding habitat. Overall, grazing land use decreased in all areas, to make space for urban areas or other more intensive land uses.

*Table 3. Summary of results*

| **Meadow bird** population changes | Habitat type | Anthrome changes 1980-2017 (in %) | Grazing land use changes 1992-2015 (in km2/grid cell); mean (μ) and std dev. (σ) | Land cover changes 1980-2017 (in %) |
|---|---|---|---|---|
| **Black-tailed Godwit** | Breeding | Urban areas: +51.4<br>Pastoral cropland: -43.7 | μ: -1.7<br>σ: 2.19 | Urban areas: +90.4<br>Herbaceous cover: -2.6<br>Mosaic vegetation: -58.7 |
| | Non-breeding | Urban areas: +98.9<br>Village, rice: +765.7<br>Village, pastoral: +162.7 | μ: -1.88<br>σ: 7.01 | Urban areas: +92.2<br>Herbaceous cover: +4.2 |
| | Resident | Urban areas: +38.5<br>Village irrigated: -25.0 | μ: -3.99<br>σ: 6.83 | Urban areas: +64.9<br>Cropland: -14.1<br>Herbaceous cover: -5.4<br>Mosaic vegetation: -28.9 |
| **Common Redshank** | Breeding | Urban areas: +45.2<br>Village, irrigated: +69.0 | μ: -0.89<br>σ: 1.74 | Urban areas: +81.4 |
| | Non-breeding | Urban areas: +207.9<br>Village, rice: +698.0<br>Village, pastoral: +177.8 | μ: -0.57<br>σ: 6.11 | Urban areas: +118.8<br>Herbaceous cover: +11.4<br>Irrigated cropland: +7.9 |
| | Resident | Urban areas: +50.6.<br>Village, rice: +77.3<br>Village, pastoral: +60.0 | μ: -2.66<br>σ: 4.43 | Urban areas: +100.3<br>Mosaic vegetation: -13.0 |

## 4.2 Black-tailed Godwit

### 4.2.1 Population trends

Figure 7 presents the population changes of the Black-tailed Godwit from 1984 to 2017 on a European scale. Additionally, it shows the trend of the Dutch breeding bird population. The national and continental trends appear very similar. No extreme changes in population size were notable until the 1990s. From 1995 to 2017, the European Black-tailed Godwit population decreased to 40% of its total population. The Dutch breeding bird population size is only 31% in comparison to 1990. The species is now significantly decreasing with 5% per year. This is also in agreement with global population changes. BirdLife International (2015) reported declines of around 30% in the last 15 years, on a global and European scale.

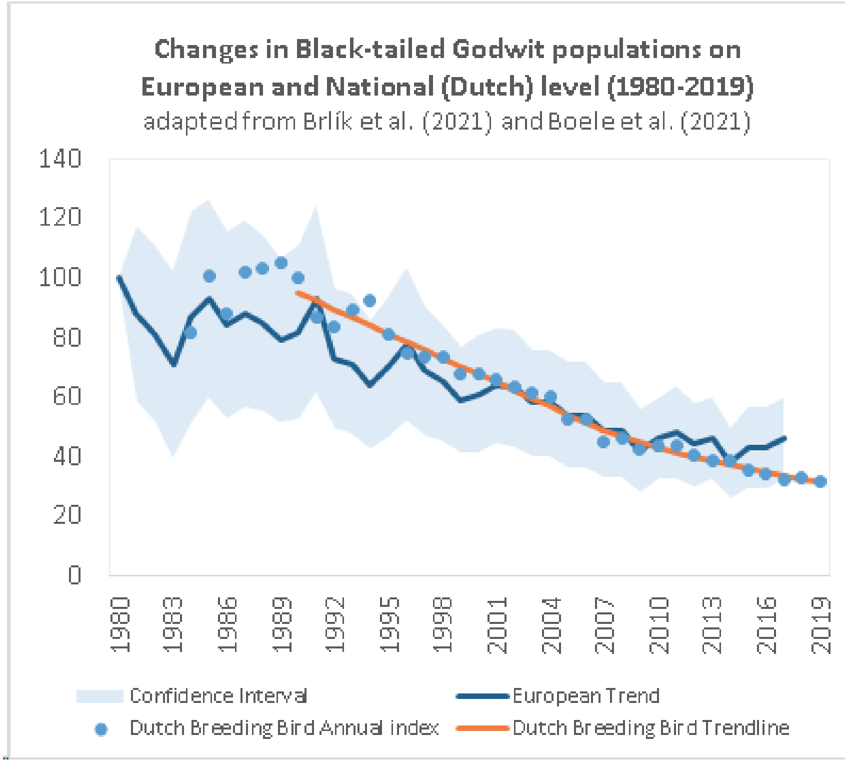



*Figure 7. Changes in Black-tailed Godwit populations on European and national (Dutch) level, 1980-2017, adapted from PECBMS (2019) and Boele et al. (2021).*

### 4.2.2 Anthrome changes

Full tables providing changes for all anthrome classes in breeding, non-breeding and resident habitat of the Black-tailed Godwit, can be found in the Appendix B.I. Maps of anthrome changes in the habitats can be found in the Appendix B.II. The following section discusses changes in the anthrome classes that are most relevant, either because a substantial change took place , or because this anthrome class is considered of importance with regards to habitat suitability of the Black-tailed Godwit.

#### 4.2.2.1 Breeding Habitat

In the breeding habitat of the Black-tailed Godwit, major changes occurred in the following anthrome classes: *Urban areas* (+51.4%); *Dense settlements* (+24.3%); *Pastoral cropland* (-43.7%); *Rangeland populated* (-18.6%); *Semi natural woodlands (remote)* (+25.3%). In the Netherlands, urban areas have expanded rapidly, at the cost of *Croplands* and *Villages*. Furthermore, especially in Germany, *Village, irrigated* and *Croplands, residential, irrigated* increase.

#### 4.2.2.2 Non-Breeding Habitat

Overall, the non-breeding habitat of the Black-tailed Godwit shows more drastic land use changes. The most relevant changes in anthrome classes were as follows: *Urban areas* (+98.9%); *Dense settlements* (+58.9%) *Village (all categories): rice, irrigated, rainfed, pastoral* (+765.7%, +86.0%, +66.1%, +162.7%); *Cropland populated, pastoral* (-60.5%, -54.6%); *Rangeland populated and remote* (-39.7%, -28.5%); *Wild remote woodlands* (-85.7%) and *Semi-natural Remote woodlands* (+42.0%).

#### 4.2.2.3 Resident Habitat

The resident habitat of the Black-tailed Godwit covers a rather small part of Europe, which underwent the following changes in anthrome classes: *Urban areas* (+38.5%); *Village irrigated, rainfed* (-25.0%, -7.6%); *Cropland, rainfed* (-13.2%). Generally, all throughout the resident habitat, land use shifted from *Village* and *Cropland* to *Urban areas* as main land use.

### 4.2.3 Grazing Land Use changes

Changes in the percentage of land used for grazing are presented in the following section. Histograms for each habitat type are shown to indicate the frequency of a certain change. Additionally, maps of the habitat showcase in what areas the biggest changes occurred.

#### 4.2.3.1 Breeding Habitat

Figure 8a presents how the changes in grazing land use in the breeding habitat of the Black-tailed Godwit are between a decrease of 23.7%points and an increase of 6.95%points. The mean change is -1.7%points. Thus, compared to 1980, in 2017, on average 1.7% less land was used for grazing in the breeding habitat of the Black-tailed Godwit. With a standard deviation of 2.19, 95% of this habitat type had a change between -6.1%point and 2.66%point. Figure 8b shows that the largest decreases were found in the most western part of Europe, Western Germany and the Netherlands. In Poland, substantial increases in grazing land use were noted between 1980 and 2017.

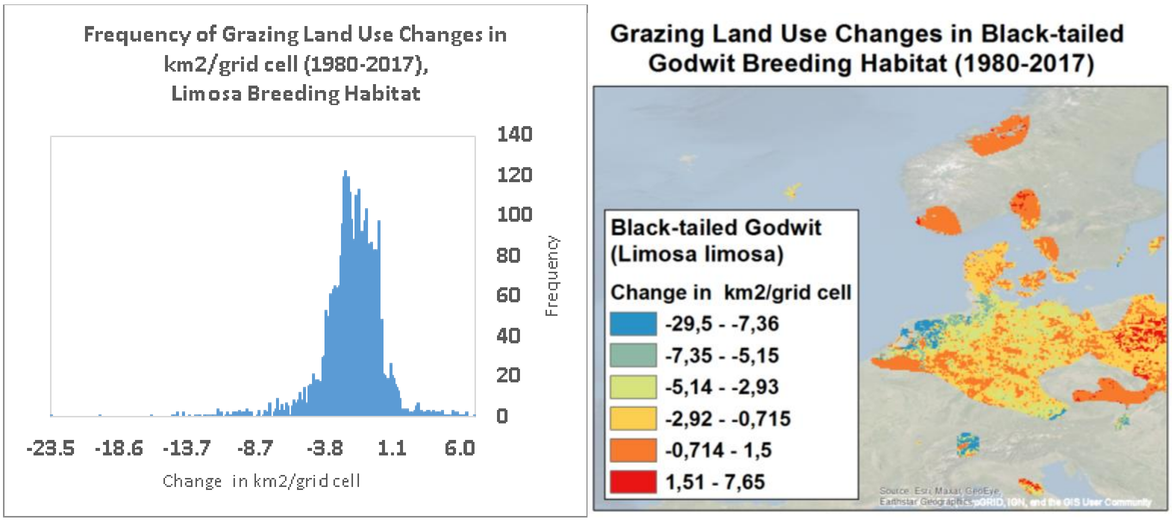
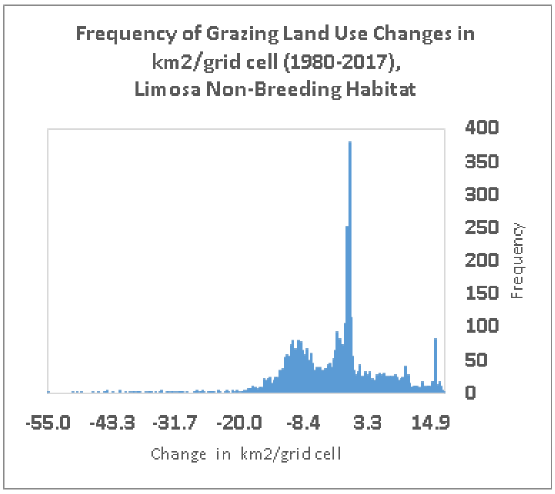



*Figure 8a. Histogram of grazing land use changes in breeding habitat of Black-tailed Godwit. Figure 8b. Corresponding map.*

#### 4.2.3.2 Non-Breeding Habitat

The non-breeding habitat of the Black-tailed Godwit shows less obvious trends, with changes varying between a decrease of 55,0%points and increase of 17.5%points. Figure 9a showcases a histogram of these changes in grazing land use. The mean is -1.88 and the standard deviation 7,01, indicating an average decrease of 1.88%points of land use, with 95% of the changes being between -15.9%points and +12.4%points. Figure 9b displays how variable changes in grazing as land use were throughout the habitat. The largest increases were noticed in the Sahel region, the coastal region of Portugal and Tunisia.



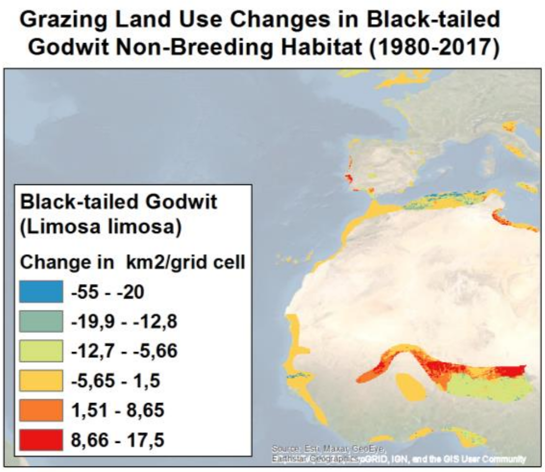
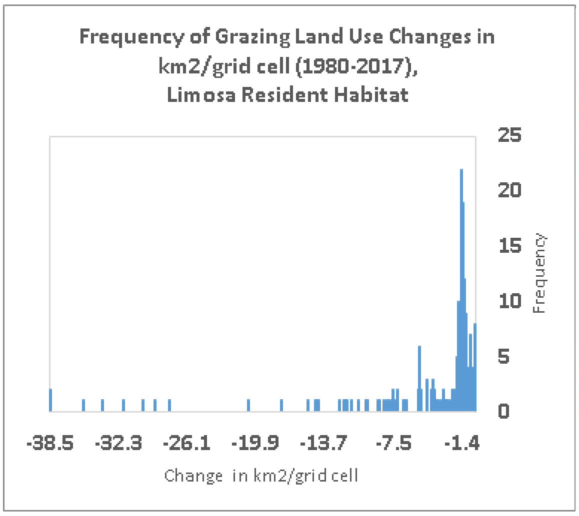




*Figure 9a. Histogram of grazing land use changes in non-breeding habitat of Black-tailed Godwit.*
*Figure 9b. Corresponding map.*

#### 4.2.3.3 Resident Habitat

In the resident habitat of the Black-tailed Godwit, only decreases in grazing land use were identified, with the decreases varying from 38.5%points to 0.0% points (no decrease). Figure 10a shows the histogram, with a mean of -3.99%points and a standard deviation of 6.83. This means that 95% of changes in the resident habitat were between -17.7%points and 0.0%points. Figure 10b shows that especially in the Netherlands, grazing land use decreased majorly, in trends similar to the surrounding Black-tailed Godwit breeding habitat mentioned above.



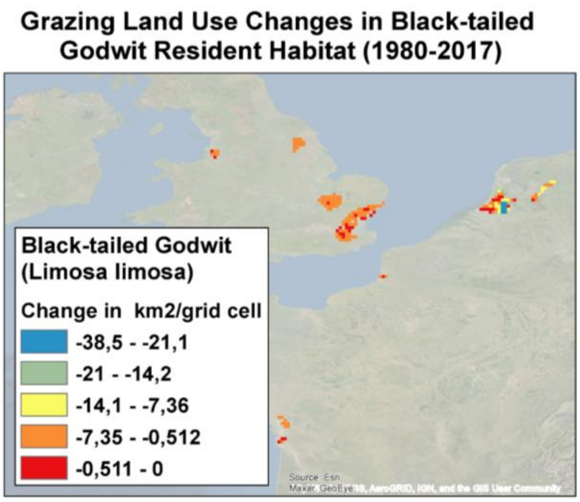




*Figure 10a. Histogram of grazing land use changes in resident habitat of Black-tailed Godwit.*
*Figure 10b. Corresponding map.*

### 4.2.4 Land cover changes

In the following section, the most relevant changes in land cover in the breeding, non-breeding and resident habitat of the Black-tailed Godwit between 1980 and 2017 will be discussed.

Percentual changes are given in brackets, with a positive percentage (+) indicating an increase and a negative percentage (-) indicating a decrease relative to the 1980 value. Changes for all 33 land cover (sub-)classes in these habitats can be found in the Appendix C, as well as full-sized maps showing where these land cover changes occurred.

#### 4.2.4.1 Breeding Habitat

In the breeding habitat of the Black-tailed Godwit, the following major and/or relevant changes in land covers took place: *Urban areas* (+90.4%); *Cropland* (-4.2%); *Herbaceous cover* (-2.6%); *Grassland* (+0.7%); *Shrub or herbaceous cover flooded brackish* (-17.0%); *Mosaic vegetation: cropland, natural* (-5.4%, -58.7%).

#### 4.2.4.2 Non-Breeding Habitat

The non-breeding habitat of the Black-tailed Godwit showcased the following changes in land covers: *Urban areas* (+92.2%), *Tree cover (all combined)* (-1.4%); *Cropland* (+2.9%); *Herbaceous cover* (+4.2%); *Irrigated croplands* (+6.0%); *Mosaic cropland* (+2.2%); *Grassland* (-2.3%).

#### 4.2.4.3 Resident Habitat

The following changes in land cover occurred in the resident habitat of the Black-tailed Godwit: Urban areas (+64.9%); Cropland (-14.1%); Herbaceous cover (-5.4%); Grassland (-4.7%); Shrub or herbaceous cover flooded, brackish (-6.2%); Mosaic natural vegetation (-28.9%).

## 4.3 Common Redshank

### 4.3.1 Population trends

European population changes of the Common Redshank from 1980 to 2017 are presented in Figure 11. Furthermore, the Dutch breeding bird population is presented as well. The trends are more uncertain. The European population trend has a wider confidence band. European population sizes are estimated to have declined to 46% of the 1980 population, with an upper and lower Confidence Level of 32% and 60% respectively. Figure 11 also shows that European and Dutch trendlines are less in agreement, which is in contrast with the Black-tailed Godwit trendlines. In the Netherlands, the population size remains at about 80% of the 1990s size. Similar to the Black-tailed Godwit, an annual decrease of less than 5% of the breeding bird population in the Netherlands is notable. On a global level, the population trends are evenly uncertain (Wetlands International, 2015).

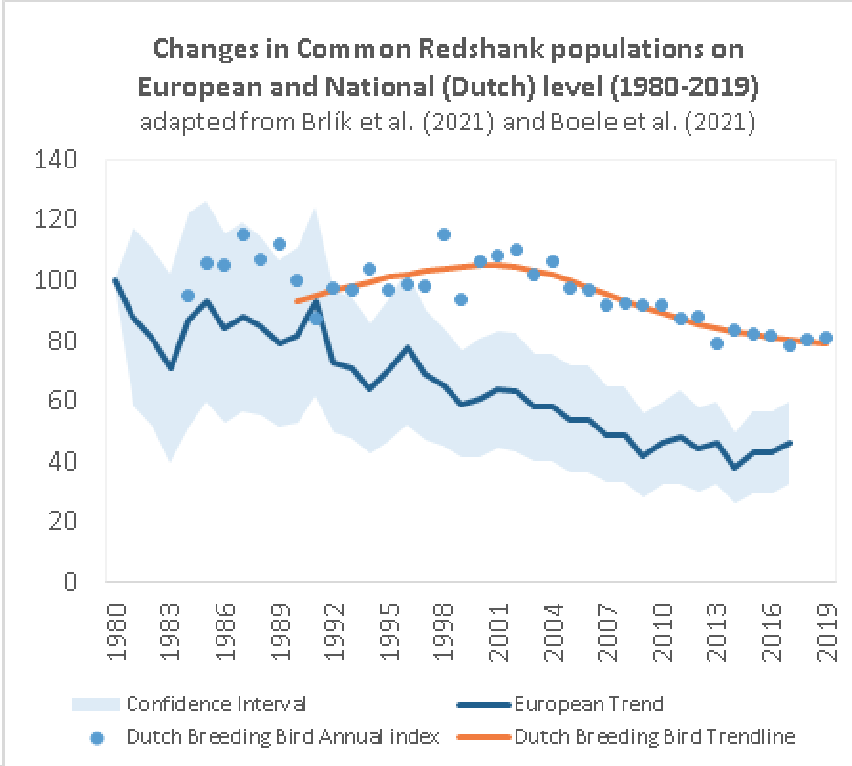



*Figure 11. Changes in Common Redshank populations on European and national (Dutch) level, 1980-2017, adapted from PECBMS (2019) and Boele et al. (2021).*

### 4.3.2 Anthrome changes

Full tables providing changes for all anthrome classes in breeding, non-breeding and resident habitat of the Common Redshank can be found in Appendix B.I. Maps of anthrome changes in the habitats can be found in Appendix B.II. The following section discusses changes in the anthrome classes that are most relevant, either because a substantial change took place, or because this anthrome class is considered of importance with regards to habitat suitability of the Common Redshank.

#### 4.3.2.1 Breeding Habitat

The breeding habitat of the Common Redshank showed substantial changes in the following anthrome classes: *Urban areas* (+45.2%); *Dense settlements* (+32.3%); *Village irrigated* (+69%); *Village rainfed* (-10.5%); *Cropland residential irrigated* (-10.5%); *Rangeland populated* (-10.3%); *Semi natural woodlands (remote)* (+17.6%). Comparable to the Black-tailed Godwit, Urban areas and dense settlements expanded around existing areas of these anthrome classes. Furthermore, rainfed agriculture was traded in for irrigated agriculture.

#### 4.3.2.2 Non-Breeding Habitat

Similar to the Black-tailed Godwit, the non-breeding habitat underwent some major changes regarding anthrome classes: *Urban areas* (+207.9%); *Dense settlements* (+64.8%); *Village (all categories): rice, irrigated, rainfed, pastoral* (+698.0%, +152.2%, +128.5%, +177.8%); *Cropland populated, pastoral* (-52.0%, -48.0%). *Rangeland residential* (+37.7%); *Rangeland populated, remote* (-39.7%, -28.5%); *Wild and semi-natural Remote woodlands* (-57.9%, -75%).

#### 4.3.2.3 Resident Habitat

In the residential habitat of Common Redshank substantial changes in anthrome class took place: *Urban areas* (+50.6%); *Dense settlements* (+43.6%) *Village*: *rice, irrigated, rainfed, pastoral* (+77.3%, +41.3%, -14.4%, +60.0%); *Cropland residential irrigated* (+36.2%); *Semi-natural Woodlands* (+63.4%).

### 4.3.3 Grazing Land Use changes

#### 4.3.3.1 Breeding Habitat

Figure 12a presents the Common Redshank (Tringa totanus) breeding habitat, showcasing a similar decrease in grazing land as in the Black-tailed Godwit breeding habitat. The changes vary between -16.9%points and +7.65%points. The mean change was a decrease of 0.89%points, with a standard deviation of 1.74. This results in 95% of the change in the Common Redshank breeding habitat being between -4.37%points and +2.59%points. Figure 12b shows that the largest increases in grazing land between 1980 and 2017 are found in Ireland and the Southern part of central Europe. Similar to the Black-tailed Godwit breeding habitat, Poland is the exception in increasing grazing land use.

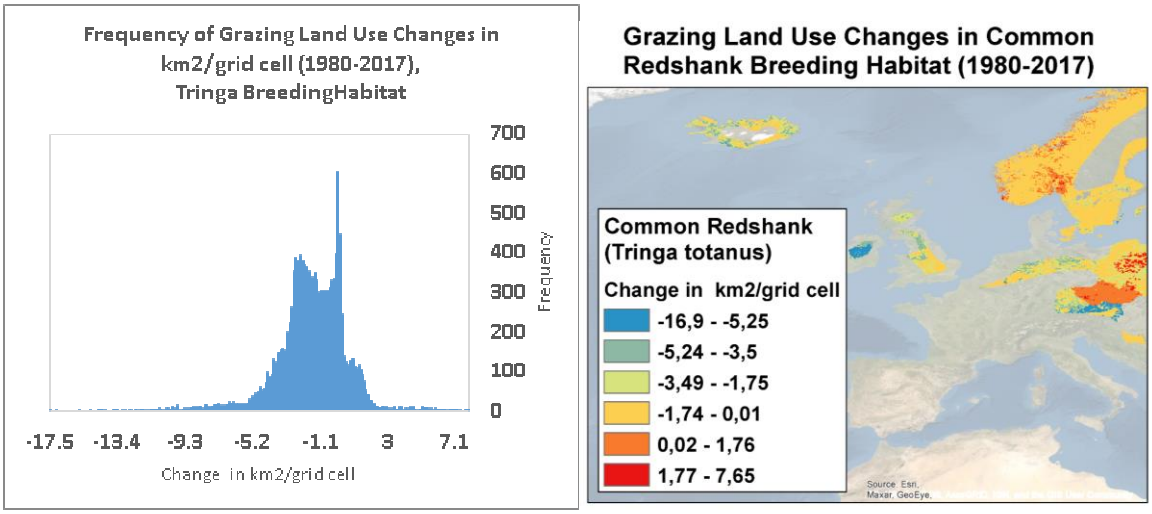
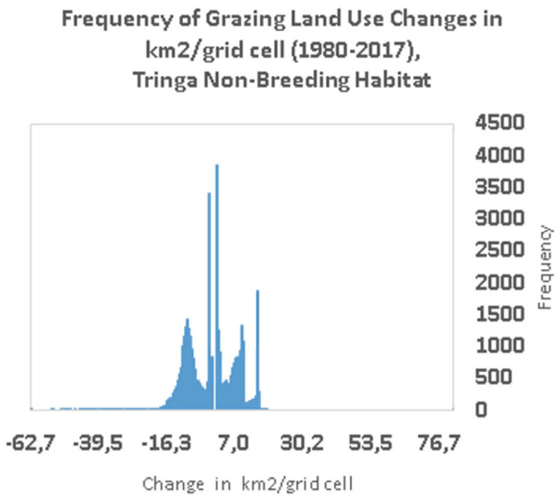



*Figure 12a. Histogram of grazing land use changes in breeding habitat of Common Redshank.*
*Figure 12b. Corresponding map.*

#### 4.3.3.2 Non-Breeding Habitat

The non-breeding habitat of the Common Redshank, covering a major part of Western and Sub-Saharan Africa, underwent some extreme grazing land use changes, with the changes varying between a 62.8%points decrease and a 81.8%points increase (Figure 13a). The mean is -0.57 and the standard deviation 6.11. Thus, 95% of the Common Redshank non-breeding area had changes in grazing land use between -12.79%points and 11.65%points. Figure 13b presents where these changes have taken place. The biggest increases can be found in the Sahel region.



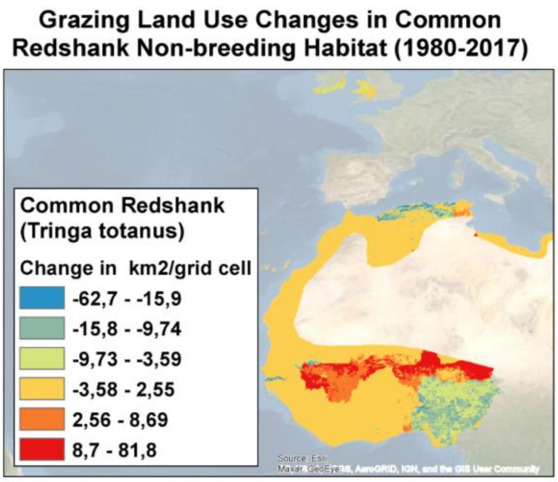
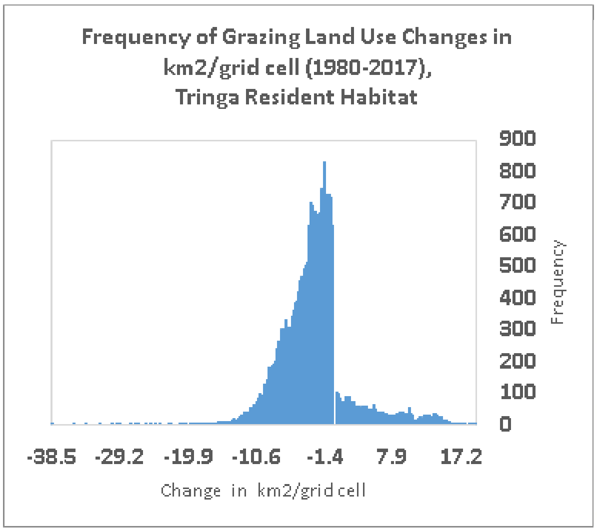




*Figure 13a. Histogram of grazing land use changes in non-breeding habitat of Common Redshank.*
*Figure 13b. Corresponding map.*

### 4.3.3.3 Resident Habitat

Figure 14a presents the frequency of percentage point changes of grazing land use in the resident habitat of the Common Redshank. Here, the changes vary between -38.5%points and +19.2%points. The mean is a decrease of 2.66%points and the standard deviation is 4.43. Therefore, in 95% of the area changes between -11.5%points and 6.2%points occurred. Figure 14b presents where these changes have taken place. The biggest decreases are in the Netherlands and southern part of central europe. The biggest increases in grazing land use are located in Tunisia and Southern Europe, especially Portugal.



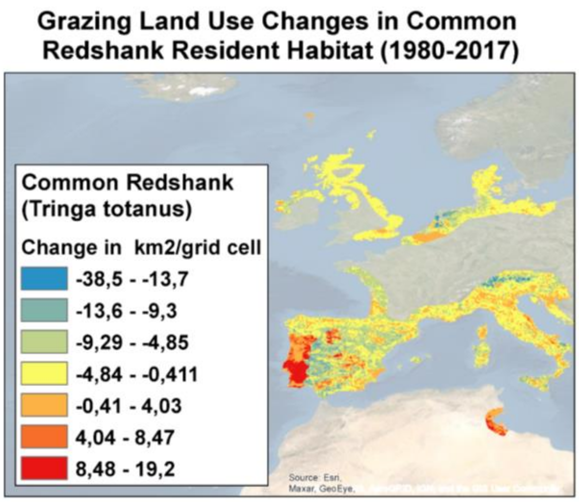




*Figure 14a. Histogram of grazing land use changes in resident habitat of Common Redshank.*
*Figure 14b. Corresponding map.*

### 4.3.4 Land cover changes

The following section discusses the most relevant changes in land cover in the breeding, non-breeding and resident habitat of the Common Redshank between 1980 and 2017. Percentual changes are given in brackets, with a positive percentage (+) indicating an increase and a negative percentage (-) indicating a decrease relative to the 1980 value. Changes for all 33 land cover (sub-)classes in these habitats can be found in the Appendices, as well as full-sized maps showing where these land cover changes occurred.

#### 4.3.4.1 Breeding Habitat

The breeding habitat of the Common Redshank underwent the following changes in land cover types: *Urban areas* (+81.4%); *Cropland* (+4.1%); *Herbaceous cover* (-1.8%); *Grassland* (-0.3%); *Shrub or herbaceous cover flooded, brackish* (-12.3%); *mosaic vegetation: cropland, natural* (-3.3%, -40.9%).

#### 4.3.4.2 Non-Breeding Habitat

The following relevant land cover changes took place in the non-breeding habitat of the Common Redshank:Urban areas (+118.8%); Tree cover (all) (+6.0%); Cropland (+5.9%); Herbaceous cover (+11.4%); Irrigated cropland (+7.9%); Mosaic cropland (+6.1%); Shrub or herbaceous cover flooded, brackish (-5.6%); Grassland (+0.1%).

#### 4.3.4.3 Resident Habitat

Lastly, the resident habitat of the Common Redshank underwent the following changes in land cover types: *Urban areas* (+100.3%); *Forest* (-6.2%); *Cropland* (-0.8%); *Herbaceous cover* (-0.4%); *Grassland* (+1.7%); *Shrub or herbaceous cover flooded brackish* (-7.3%); *Mosaic natural vegetation* (-13.0%).

# 5. Discussion

## 5.1 Reflection on results

Section 4.2.1 and Section 4.3.1 described decreases in the populations of the Black-tailed Godwit and the Common Redshank. In this section, possible links to the changes in land use change will be discussed. Section 2.3 bird migration theory described how different habitats may be suitable for the breeding, non-breeding and resident habitat of one bird species. Thus, each habitat will be discussed individually to investigate what land use changes may have had a role in the decline of the bird population size.

### 5.1.1 Breeding habitat

Most suitable anthromes for the breeding habitat of the Black-tailed Godwit are *Croplands, pastoral* and *Rangeland, remote*. Decreased with 95.3%. Most suitable land covers are *Herbaceous cover*; *Cropland, irrigated or flooded*; *Grassland*; *Herbaceous cover, flooded, brackish*; *water bodies*: these decreased with 48.9%. Furthermore, grazing land decreased. These all made the habitat conditions for the Black-tailed Godwit less optimal. It is therefore proposed that land use changes in the breeding habitat had a part in the population decrease, as habitat selection is important for population.

The most suitable anthrome classes for the Common Redshank breeding habitats are *Croplands, pastoral* and *Rangeland, pastoral*. The total acreage of these classes decreased with 92.7%. The most suitable land covers are the same as for the Black-tailed Godwit breeding habitat. In the Common Redshank breeding habitat, these decreased by 39.6%. Furthermore, grazing land showed a declining trend as well, however, a bit less clear than for the Black-tailed Godwit, as the Breeding habitat of the Common Redshank does not include areas of the Godwit that showed the steepest declines, such as the Netherlands. Similarly, population trends of the Common Redshank also declined less steeply than those of the Black-tailed Godwit. Overall, it can be said that the land use and cover changes made the breeding habitat conditions of the Common Redshank less optimal, and therefore, they are quite likely to have had an effect on the declines of the Common Redshank.

### 5.1.2 Non-breeding habitat

For the non-breeding habitat of the Black-tailed Godwit, the most suitable anthromes identified are *Village, rice*; *Croplands, irrigated*; *Croplands, pastoral, Rangeland remote*: the acreage of these anthromes together increased with 19.7%. However, the most suitable land covers are *Cropland, irrigated or flooded*; *Grassland*; *Herbaceous cover, flooded, brackish*; *water bodies*, and the total acreage of these land covers decreased with 70.5%. Thus, the land use classes became more suitable for the non-breeding habitat of the Black-tailed Godwit, while the land cover suitability decreased. The main identified land use causing this was the increase in *Village, Rice*, a suitable non-breeding habitat type for the Black-tailed Godwit, which increased enormously (+765%). Grazing land use changes made the ambiguity of the breeding habitat arise even more: no visible trend was shown, with grazing land increasing majorly in some parts, while decreasing in others. Therefore, even though the changes in this landscape were more radical, they did not very clearly make the land more or less fitting for the non-breeding of the Black-tailed Godwit. Thus, it cannot be said with certainty that these changes had a part in the decline of the Black-tailed Godwit. It could be that increases in suitable land use classes halted the changes by providing more non-breeding habitat.

Similar to its breeding range, the most suitable anthrome classes in the non-breeding habitat of the Common Redshank are *Croplands, pastoral* and *Rangeland, pastoral*. The total acreage of these land use types declined with 20.6%. A clear difference with the non-breeding habitat of the Black-tailed Godwit can be noted. This mostly has to do with the fact that the Common Redshank does not utilise irrigated rice fields as a non-wintering habitat. The most suitable land cover types for the non-breeding habitat of the Common Redshank are *Cropland, irrigated or flooded*; *Grassland*; *Herbaceous cover, flooded, brackish*; *water bodies*, with a total decrease in acreage of 47.8%. Grazing land use changes were comparable to the non-breeding habitat of the Black-tailed Godwit: even though grazing land use decreased on average, throughout the habitat, enormous differences were observed. It is thus, evenly difficult to assess to what extent the non-breeding land use changes had an effect on Common Redshank population declines.

### 5.1.3 Resident habitat

Resident habitat requirements were not defined by BirdLife International (2016; 2017). It is assumed that the resident habitat is similar to the breeding and non-breeding habitat. The resident habitat of the Black-tailed Godwit covers only a small part of Europe, in which none of the most suitable anthrome classes for Black-tailed Godwit breeding were found. The fact that the Black-tailed Godwit still occurs and breeds in this habitat, could be related to the high site fidelity of this species (Ausden & Bolton, 2012). Increases in urban areas were similar to the breeding habitat. Furthermore, grazing land use decreased. It is thus fairly likely that the changes in the resident habitat have had a negative influence on the Black-tailed Godwit population size.

The Common Redshank resident habitat showed more similarities with the non-breeding habitat. Grazing land use increased in some parts, but decreased in others. The same is the case for the suitable anthromes and land covers. Urban areas increased, but pastoral lands did as well. Similarly to the non-breeding habitat, it is unclear if changes in the resident habitat had an influence on Common Redshank populations.

## 5.2 Limitations

As presented in *section 5.1. Reflection on results*, establishing a clear causal relationship between land use and cover changes on a large scale has proven to be challenging. The research was limited by the fact that only European and Dutch bird indices were available. For a more thorough analysis, geographic and seasonal data on European and African bird population could be used. This way, the study could clearly indicate specific areas where bird populations are declining in the breeding, non-breeding and resident habitat. By adding a temporal dimension, it can be analysed whether bird populations decline in the breeding or non-breeding season. Furthermore, grazing land use was expressed in km2 per gridcell. In future studies, it is recommended to express this numerical data in percentual change, as not all grid cells represent the same sized acreage. Lastly, as mentioned in the theory, habitat specifications differ for the breeding, non-breeding and resident area. In the breeding habitat, grasslands are of major importance, where in the non-breeding habitat the meadow birds also live on various other habitats, such as saltmarshes. Therefore, the grazing land use changes may have been of more importance to the breeding habitat. In future studies, this can be omitted by studying more land use types in-depth. For the Black-tailed Godwit, irrigated rice fields would be a viable option.

## 5.3 Implications

Even though the study was limited in its ability to find a clear causal relationship, it has still brought attention to the fact that major changes occurred in all habitat types, making the habitat less suitable in many cases. There is a large focus on bird conservation within the borders of the Netherlands and within the borders of Europe. This research found the most impactful land use changes to be in the breeding areas, which would confirm the focus on these areas. However, it is still valuable to extend these boundaries to further explore land use changes. The disappearance of migratory birds within borders may as well have something to do with what happens outside, whether it is in land use categories less studied, or anthropogenic actions such as hunting. As data on bird species outside of Europe was not available for this research, it is suggested that bird monitoring in Africa requires more priorities. There have already been projects initiated such as the Bird Population Monitoring (Senyatso et al., 2008).

# 6. Conclusions

*What land use changes have occurred in the breeding, non-breeding and permanent-residential habitat of Western European meadow birds and how has this influenced their population changes?*

Overall, urbanisation has played a major role in all habitat types of the meadow birds studied. In the breeding habitat, land use and cover changes most likely had a negative effect, as parts of habitat changed into unsuitable land use and land cover types. In non-breeding habitats, the effect of land-use and land cover is less clear. What can be said is that the changes in the non-breeding habitat were more extreme. However, evidence of land use and cover changes did not point in one direction. It is thus difficult to establish how the changes affected population sizes.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# Appendix A. Habitat suitability classifications

## A.I. Anthrome classes

*Table 4. Anthrome classes and habitat suitability for meadow birds, adapted from Ellis et al, (2010), Birdlife International (2016), Birdlife International (2017).*

| ***Land Cover Type suitability per habitat*** | Black-tailed Godwit breeding | Black-tailed Godwit non-breeding | Common Redshank breeding | Common Redshank non-breeding |
|---|---|---|---|---|
| 11 Urban | not suitable | not suitable | not suitable | not suitable |
| 12 Dense settlements | not suitable | not suitable | not suitable | not suitable |
| 21 Village, Rice | possibly suitable | preferred | possibly suitable | possibly suitable |
| 22 Village, Irrigated | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 23 Village, Rainfed | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 24 Village, Pastoral | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 31 Croplands, residential irrigated | possibly suitable | preferred | possibly suitable | possibly suitable |
| 32 Croplands, residential rainfed | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 33 Croplands, populated | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 34 Croplands, pastoral | preferred | preferred | preferred | preferred |
| 41 Rangeland, residential | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 42 Rangeland, populated | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 43 Rangeland, remote | preferred | preferred | preferred | preferred |
| 51 Semi-natural woodlands, residential | not suitable | not suitable | not suitable | not suitable |
| 52 Semi-natural woodlands, populated | not suitable | not suitable | not suitable | not suitable |

| | | | | |
|---|---|---|---|---|
| 53 Semi-natural woodlands, remote | not suitable | not suitable | not suitable | not suitable |
| 54 Semi-natural treeless and barren lands | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 61 Wild, remote - woodlands | not suitable | not suitable | not suitable | not suitable |
| 62 Wild, remote - treeless & barren | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 63 Wild, remote - ice | not suitable | not suitable | not suitable | not suitable |
| 70 No definition | not suitable | not suitable | not suitable | not suitable |

## A.II. Land cover types

*Table 5. Land cover types and habitat suitability for meadow birds, adapted from ESA (2017), Birdlife International (2016), Birdlife International (2017).*

| | Black-tailed Godwit Breeding | Black-tailed Godwit non-breeding | Common Redshank breeding | Common Redshank non-breeding |
|---|---|---|---|---|
| 10 Cropland, rainfed | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 11 Herbaceous cover | Preferred | possibly suitable | Preferred | possibly suitable |
| 12 Tree or shrub cover | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 20 Cropland, irrigated or post-flooding | Preferred | Preferred | Preferred | Preferred |
| 30 Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%) | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 40 Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%) | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 50 Tree cover, broadleaved, evergreen, closed to open (>15%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 60 Tree cover, broadleaved, deciduous, closed to open (>15%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 61 Tree cover, broadleaved, deciduous, closed (>40%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 62 Tree cover, broadleaved, deciduous, open (15-40%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 70 Tree cover, needleleaved, evergreen, closed to open (>15%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 71 Tree cover, needleleaved, evergreen, closed (>40%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 72 Tree cover, needleleaved, evergreen, open (15-40%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |

| | | | | |
|---|---|---|---|---|
| 80 Tree cover, needleleaved, deciduous, closed to open (>15%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 81 Tree cover, needleleaved, deciduous, closed (>40%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 82 Tree cover, needleleaved, deciduous, open (15–40%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 90 Tree cover, mixed leaf type (broadleaved and needleleaved) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 100 Mosaic tree and shrub (>50%) / herbaceous cover (<50%) | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 110 Mosaic herbaceous cover (>50%) / tree and shrub (<50%) | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 120 Shrubland | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 121 Evergreen shrubland | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 122 Deciduous shrubland | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 130 Grassland | Preferred | Preferred | Preferred | Preferred |
| 140 Lichens and mosses | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 150 Sparse vegetation (tree, shrub, herbaceous cover) (<15%) | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 152 Sparse shrub (<15%) | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 153 Sparse herbaceous cover (<15%) | possibly suitable | possibly suitable | possibly suitable | possibly suitable |
| 160 Tree cover, flooded, fresh or brakish water | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 170 Tree cover, flooded, saline water | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 180 Shrub or herbaceous cover, flooded, fresh/saline/brakish water | Preferred | Preferred | Preferred | Preferred |
| 190 Urban areas | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 200 Bare areas | possibly | possibly | possibly | possibly |

| | | | | |
|---|---|---|---|---|
| | suitable | suitable | suitable | suitable |
| 201 Consolidated bare areas | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 202 Unconsolidated bare areas | Unsuitable | Unsuitable | Unsuitable | Unsuitable |
| 210 Water bodies | Preferred | Preferred | Preferred | Preferred |
| 220 Permanent snow and ice | Unsuitable | Unsuitable | Unsuitable | Unsuitable |

# Appendix B. Anthrome changes

## B.I Tables

*Table 6. Anthromes changes Black-tailed Godwit Breeding habitat*

| Black-tailed Godwit breeding habitat | 1980 | 2000 | 2017 | % change |
|---|---|---|---|---|
| 11 Urban | 2.201 | 2.917 | 3.333 | 33.958 |
| 12 Dense settlements | 2.826 | 3.014 | 3.514 | 19.565 |
| 21 Village, Rice | | | | |
| 22 Village, Irrigated | 1.049 | 1.014 | 1.167 | 10.119 |
| 23 Village, Rainfed | 31.111 | 29.903 | 27.847 | -11.721 |
| 24 Village, Pastoral | | | | |
| 31 Croplands, residential irrigated | 1.118 | 1.069 | 1.146 | 2.424 |
| 32 Croplands, residential rainfed | 49.882 | 49.701 | 49.583 | -0.602 |
| 33 Croplands, populated | 1.486 | 1.625 | 1.757 | 15.415 |
| 34 Croplands, pastoral | 0.111 | 0.104 | 0.063 | -77.778 |
| 41 Rangeland, residential | | | | |
| 42 Rangeland, populated | 1.535 | 1.243 | 1.250 | -22.778 |
| 43 Rangeland, remote | 5.153 | 4.736 | 4.646 | -10.912 |
| 51 Semi-natural woodlands, residential | 5.382 | 5.389 | 5.944 | 9.463 |
| 52 Semi-natural woodlands, populated | 5.160 | 5.333 | 5.667 | 8.946 |
| 53 Semi-natural woodlands, remote | 2.007 | 2.389 | 2.514 | 20.166 |
| 54 Semi-natural treeless and barren lands | 0.576 | 0.722 | 0.750 | 23.148 |
| 61 Wild, remote - woodlands | 1.903 | 1.993 | 1.965 | 3.180 |
| 62 Wild, remote - treeless & barren | 3.049 | 3.396 | 3.403 | 10.408 |
| 63 Wild, remote - ice | 1.424 | 1.424 | 1.424 | 0.000 |
| 70 No definition | 0.007 | 0.007 | 0.007 | 0.000 |

*Table 7. Anthromes changes Black-tailed Godwit Non-breeding habitat*

| Black-tailed Godwit non-breeding habitat | 1980 | 2000 | 2017 | % change |
|---|---|---|---|---|
| 11 Urban | 1.208 | 1.715 | 2.403 | 49.711 |
| 12 Dense settlements | 1.236 | 1.549 | 1.965 | 37.102 |
| 21 Village, Rice | 0.243 | 0.590 | 2.104 | 88.449 |
| 22 Village, Irrigated | 2.375 | 3.479 | 4.417 | 46.226 |
| 23 Village, Rainfed | 23.569 | 31.014 | 39.139 | 39.780 |
| 24 Village, Pastoral | 0.410 | 0.750 | 1.076 | 61.935 |
| 31 Croplands, residential irrigated | 2.236 | 2.792 | 2.861 | 21.845 |
| 32 Croplands, residential rainfed | 74.910 | 73.854 | 67.743 | -10.579 |
| 33 Croplands, populated | 12.847 | 8.062 | 5.076 | -153.078 |
| 34 Croplands, pastoral | 1.056 | 0.667 | 0.479 | -120.290 |
| 41 Rangeland, residential | 10.646 | 10.451 | 10.535 | -1.055 |
| 42 Rangeland, populated | 13.618 | 10.118 | 8.208 | -65.905 |
| 43 Rangeland, remote | 2.507 | 2.306 | 1.792 | -39.922 |
| 51 Semi-natural woodlands, residential | 1.333 | 1.403 | 1.264 | -5.494 |
| 52 Semi-natural woodlands, populated | 0.972 | 0.958 | 0.840 | -15.702 |
| 53 Semi-natural woodlands, remote | 0.215 | 0.243 | 0.306 | 29.545 |
| 54 Semi-natural treeless and barren lands | 13.139 | 12.562 | 12.417 | -5.817 |
| 61 Wild, remote - woodlands | 0.049 | 0.049 | 0.007 | -600.043 |
| 62 Wild, remote - treeless & barren | 1.743 | 1.750 | 1.681 | -3.719 |
| 63 Wild, remote - ice | | | | |
| 70 No definition | | | | |

*Table 8. Anthromes changes Black-tailed Godwit Resident habitat*

| Black-tailed Godwit resident habitat | 1980 | 2000 | 2017 | % change |
|---|---|---|---|---|
| 11 Urban | 0.181 | 0.229 | 0.250 | 27.778 |
| 12 Dense settlements | 0.014 | 0.014 | 0.014 | 0.000 |
| 21 Village, Rice | | | | |
| 22 Village, Irrigated | 0.056 | 0.069 | 0.042 | -33.333 |
| 23 Village, Rainfed | 0.917 | 0.819 | 0.847 | -8.197 |
| 24 Village, Pastoral | | | | |
| 31 Croplands, residential irrigated | | | | |
| 32 Croplands, residential rainfed | 0.264 | 0.306 | 0.299 | 11.628 |
| 33 Croplands, populated | 0.007 | | | |
| 34 Croplands, pastoral | 0.014 | 0.014 | | |
| 41 Rangeland, residential | | | | |
| 42 Rangeland, populated | | | | |
| 43 Rangeland, remote | | | | |
| 51 Semi-natural woodlands, residential | 0.014 | 0.014 | 0.014 | 0.000 |
| 52 Semi-natural woodlands, populated | | | | |
| 53 Semi-natural woodlands, remote | | | | |
| 54 Semi-natural treeless and barren lands | | | | |
| 61 Wild, remote - woodlands | | | | |
| 62 Wild, remote - treeless & barren | | | | |
| 63 Wild, remote - ice | | | | |
| 70 No definition | | | | |

*Table 9. Anthromes changes Common Redshank Breeding habitat*

| Common Redshank Breeding habitat | 1980 | 2000 | 2017 | % change |
|---|---|---|---|---|
| 11 Urban | 2.306 | 2.931 | 3.347 | 31.120 |
| 12 Dense settlements | 2.667 | 2.958 | 3.528 | 24.409 |
| 21 Village, Rice | | | | |
| 22 Village, Irrigated | 0.299 | 0.347 | 0.507 | 41.096 |
| 23 Village, Rainfed | 26.076 | 24.937 | 23.340 | -11.723 |
| 24 Village, Pastoral | | | | |
| 31 Croplands, residential irrigated | 0.729 | 0.646 | 0.653 | -11.702 |
| 32 Croplands, residential rainfed | 53.181 | 52.264 | 51.472 | -3.319 |
| 33 Croplands, populated | 3.354 | 3.528 | 3.674 | 8.696 |
| 34 Croplands, pastoral | 0.389 | 0.410 | 0.375 | -3.704 |
| 41 Rangeland, residential | | | | |
| 42 Rangeland, populated | 1.889 | 1.625 | 1.694 | -11.475 |
| 43 Rangeland, remote | 7.431 | 6.972 | 6.889 | -7.863 |
| 51 Semi-natural woodlands, residential | 14.451 | 14.090 | 14.924 | 3.164 |
| 52 Semi-natural woodlands, populated | 23.243 | 22.111 | 22.042 | -5.451 |
| 53 Semi-natural woodlands, remote | 17.014 | 19.431 | 20.000 | 14.931 |
| 54 Semi-natural treeless and barren lands | 2.764 | 2.951 | 2.972 | 7.009 |
| 61 Wild, remote - woodlands | 28.174 | 28.250 | 28.042 | -0.471 |
| 62 Wild, remote - treeless & barren | 16.049 | 16.562 | 16.556 | 3.062 |
| 63 Wild, remote - ice | 2.528 | 2.528 | 2.528 | 0.000 |
| 70 No definition | | | | |

*Table 10. Anthromes changes Common Redshank Non-breeding habitat*

| Common Redshank Non-breeding habitat | 1980 | 2000 | 2017 | % change |
|---|---|---|---|---|
| 11 Urban | 0.701 | 1.215 | 2.160 | 67.524 |
| 12 Dense settlements | 1.264 | 1.562 | 2.083 | 39.333 |
| 21 Village, Rice | 0.708 | 2.097 | 5.653 | 87.469 |
| 22 Village, Irrigated | 1.292 | 2.312 | 3.257 | 60.341 |
| 23 Village, Rainfed | 25.632 | 41.924 | 58.562 | 56.231 |
| 24 Village, Pastoral | 0.812 | 1.590 | 2.257 | 64.000 |
| 31 Croplands, residential irrigated | 1.778 | 2.312 | 2.576 | 30.997 |
| 32 Croplands, residential rainfed | 155.583 | 168.236 | 164.646 | 5.504 |
| 33 Croplands, populated | 39.556 | 27.278 | 18.986 | -108.339 |
| 34 Croplands, pastoral | 0.896 | 0.604 | 0.465 | -92.538 |
| 41 Rangeland, residential | 25.854 | 31.611 | 35.611 | 27.399 |
| 42 Rangeland, populated | 78.528 | 60.083 | 50.361 | -55.929 |
| 43 Rangeland, remote | 39.583 | 35.208 | 31.660 | -25.027 |
| 51 Semi-natural woodlands, residential | 4.097 | 4.229 | 4.646 | 11.809 |
| 52 Semi-natural woodlands, populated | 6.986 | 5.549 | 4.319 | -61.736 |
| 53 Semi-natural woodlands, remote | 1.104 | 0.597 | 0.465 | -137.314 |
| 54 Semi-natural treeless and barren lands | 57.333 | 55.257 | 54.056 | -6.064 |
| 61 Wild, remote - woodlands | 0.028 | 0.021 | 0.007 | -300.029 |
| 62 Wild, remote - treeless & barren | 40.465 | 40.514 | 40.431 | -0.086 |
| 63 Wild, remote - ice | | | | |
| 70 No definition | | | | |

*Table 11. Anthromes changes Common Redshank Resident habitat*

| Common Redshank Resident habitat | 1980 | 2000 | 2017 | % change |
|---|---|---|---|---|
| 11 Urban | 3.035 | 3.812 | 4.569 | 33.587 |
| 12 Dense settlements | 3.347 | 3.861 | 4.806 | 30.347 |
| 21 Village, Rice | 0.153 | 0.201 | 0.271 | 43.590 |
| 22 Village, Irrigated | 5.292 | 6.903 | 7.479 | 29.248 |
| 23 Village, Rainfed | 31.465 | 28.181 | 26.931 | -16.839 |
| 24 Village, Pastoral | 0.069 | 0.097 | 0.111 | 37.500 |
| 31 Croplands, residential irrigated | 5.424 | 7.458 | 7.389 | 26.598 |
| 32 Croplands, residential rainfed | 65.403 | 59.319 | 57.333 | -14.075 |
| 33 Croplands, populated | 21.535 | 22.201 | 21.326 | -0.977 |
| 34 Croplands, pastoral | 1.549 | 1.854 | 1.653 | 6.302 |
| 41 Rangeland, residential | 0.257 | 0.313 | 0.271 | 5.128 |
| 42 Rangeland, populated | 4.944 | 4.979 | 3.937 | -25.573 |
| 43 Rangeland, remote | 4.597 | 4.986 | 4.646 | 1.046 |
| 51 Semi-natural woodlands, residential | 8.847 | 9.854 | 10.458 | 15.405 |
| 52 Semi-natural woodlands, populated | 5.910 | 6.708 | 7.278 | 18.798 |
| 53 Semi-natural woodlands, remote | 1.194 | 1.583 | 1.951 | 38.790 |
| 54 Semi-natural treeless and barren lands | 8.993 | 9.660 | 11.694 | 23.100 |
| 61 Wild, remote - woodlands | 0.215 | 0.243 | 0.153 | -40.909 |
| 62 Wild, remote - treeless & barren | 0.139 | 0.153 | 0.111 | -25.000 |
| 63 Wild, remote - ice | 0.507 | 0.507 | 0.507 | 0.000 |
| 70 No definition | | | | |

## B.II Maps

*Figure 15. Anthrome map Black-tailed Godwit Breeding habitat (Klein Goldewijk et al., 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

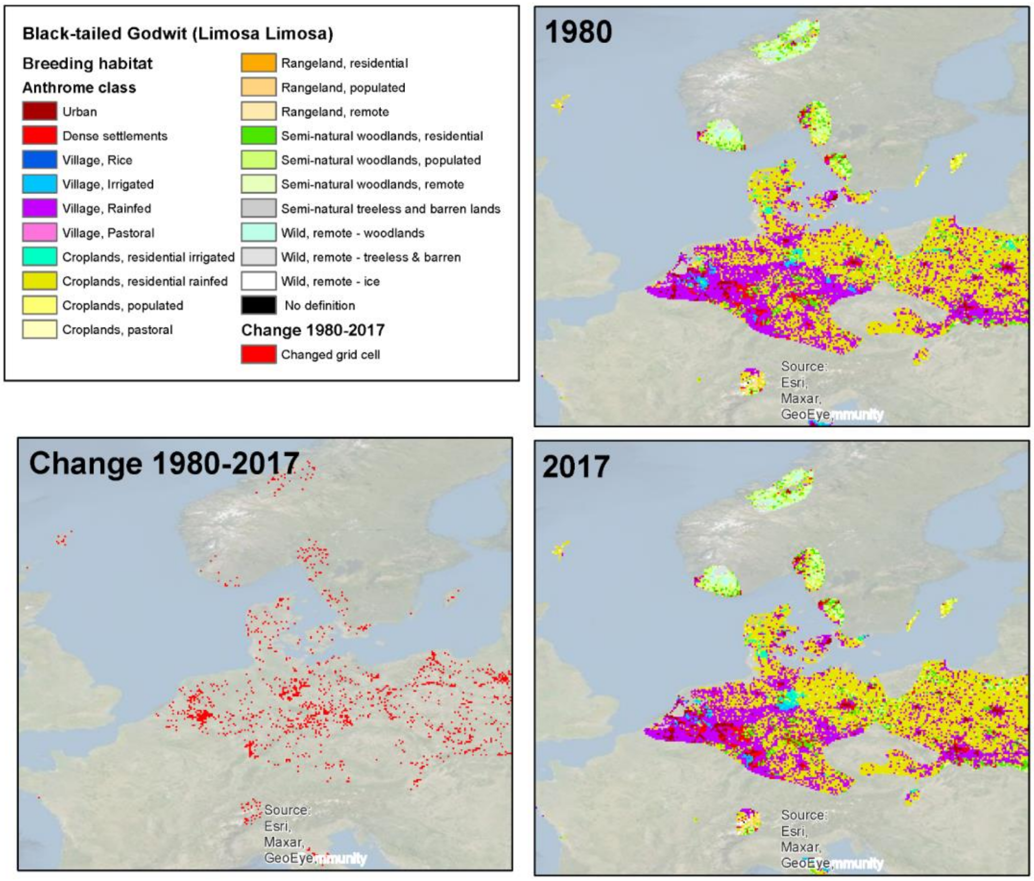


*Figure 16. Anthrome map Black-tailed Godwit Non-breeding habitat (Klein Goldewijk et al., 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

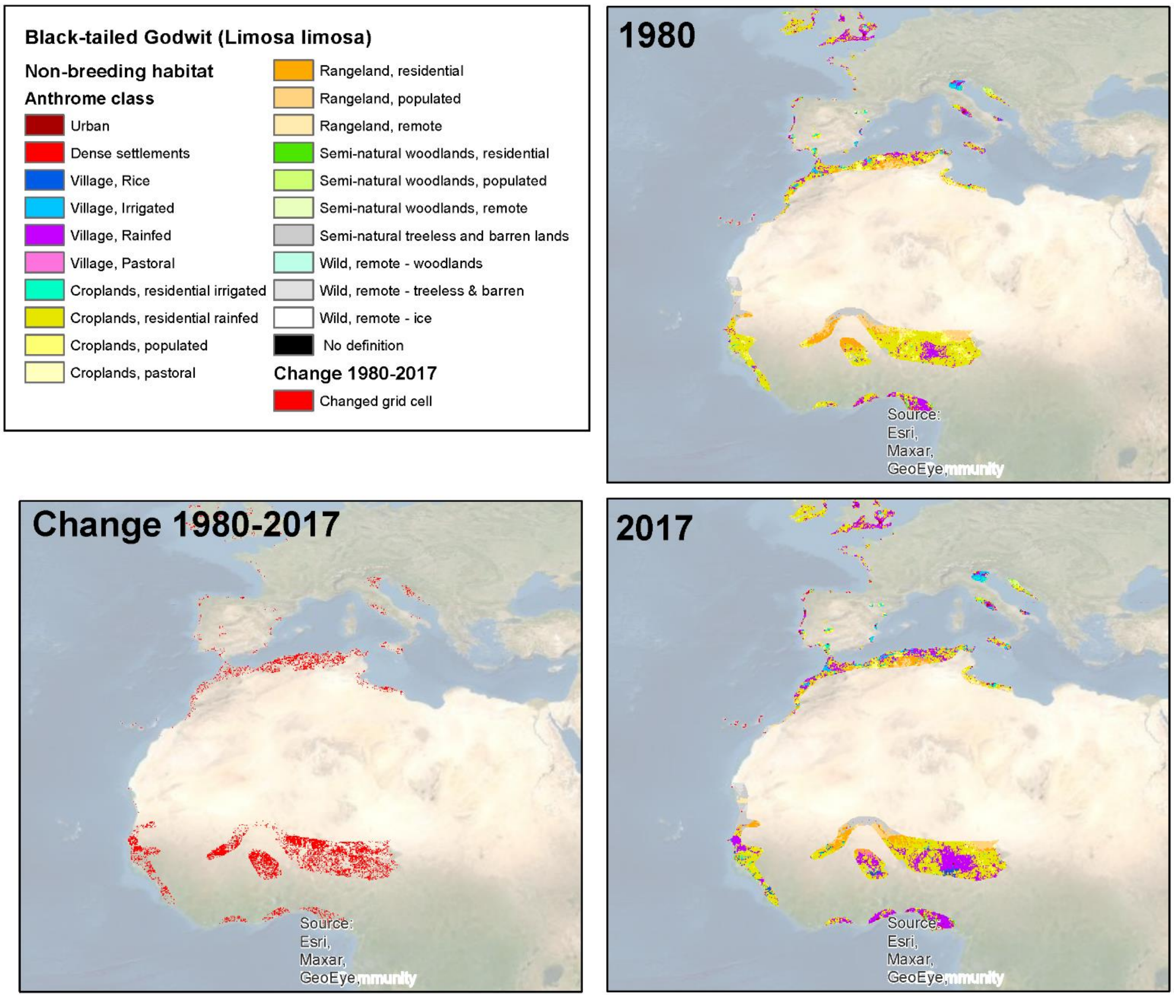


*Figure 17. Anthrome map Black-tailed Godwit Resident habitat (Klein Goldewijk et al., 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

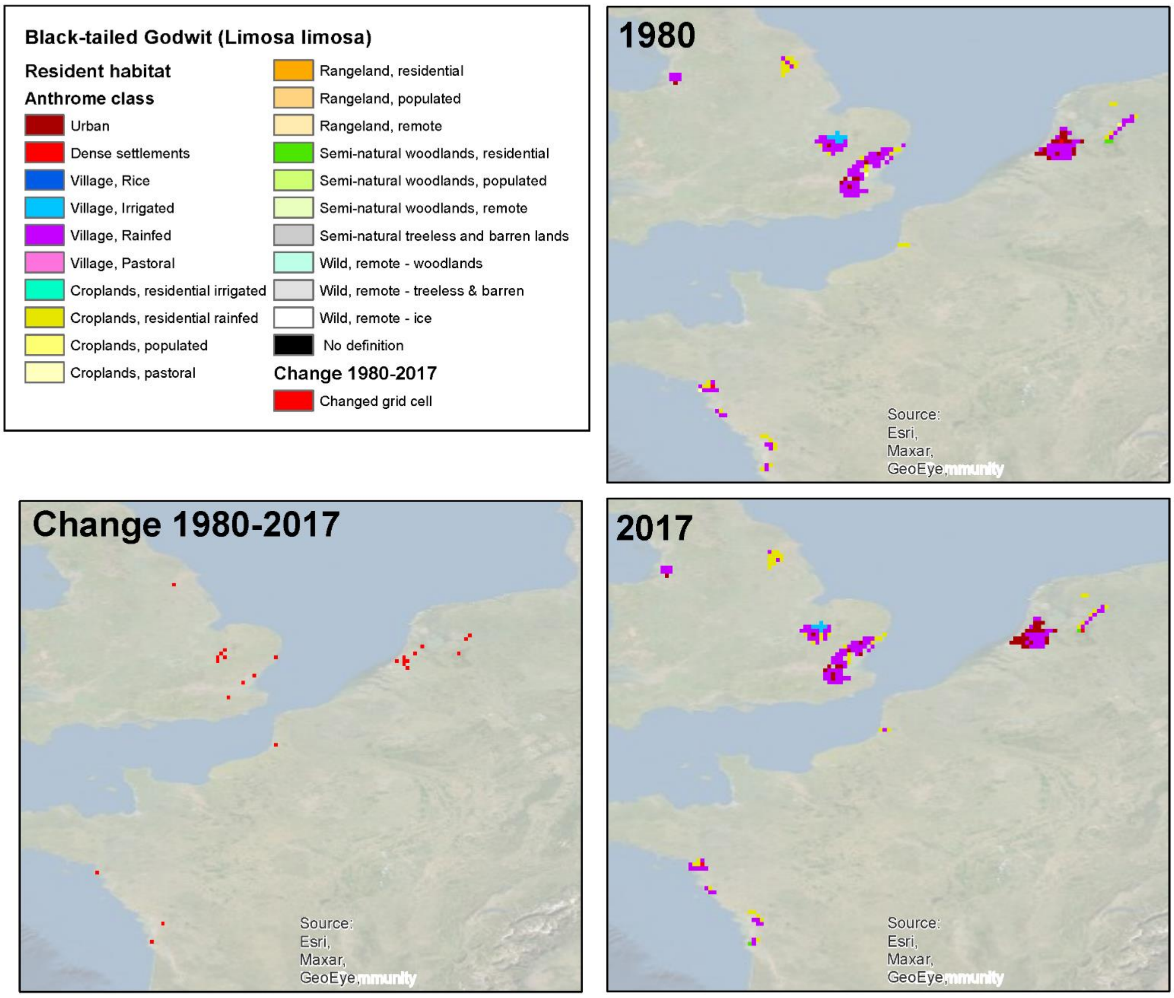


*Figure 18. Anthrome map Common Redshank Breeding habitat (Klein Goldewijk et al., 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

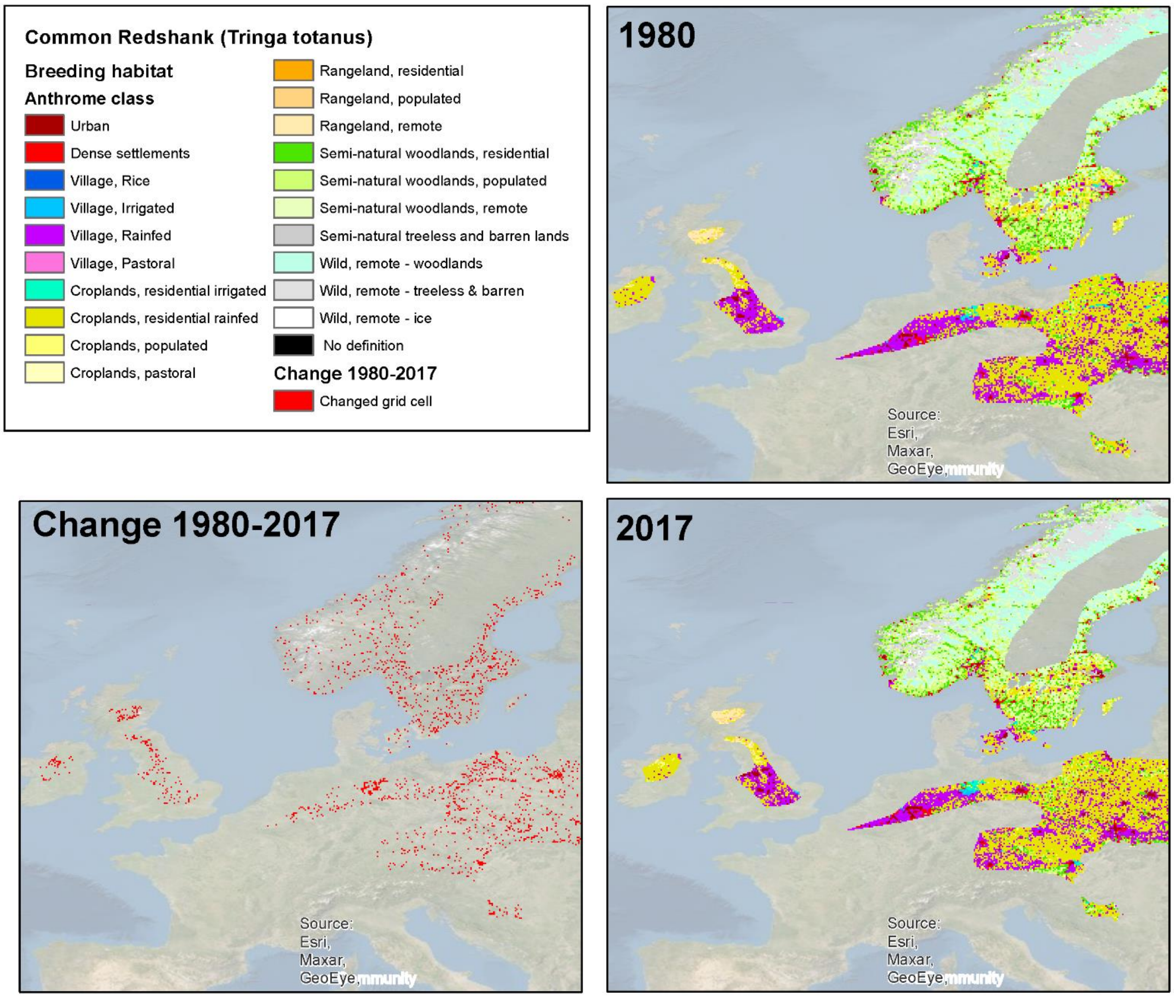


*Figure 19. Anthrome map Common Redshank Non-breeding habitat (Klein Goldewijk et al., 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

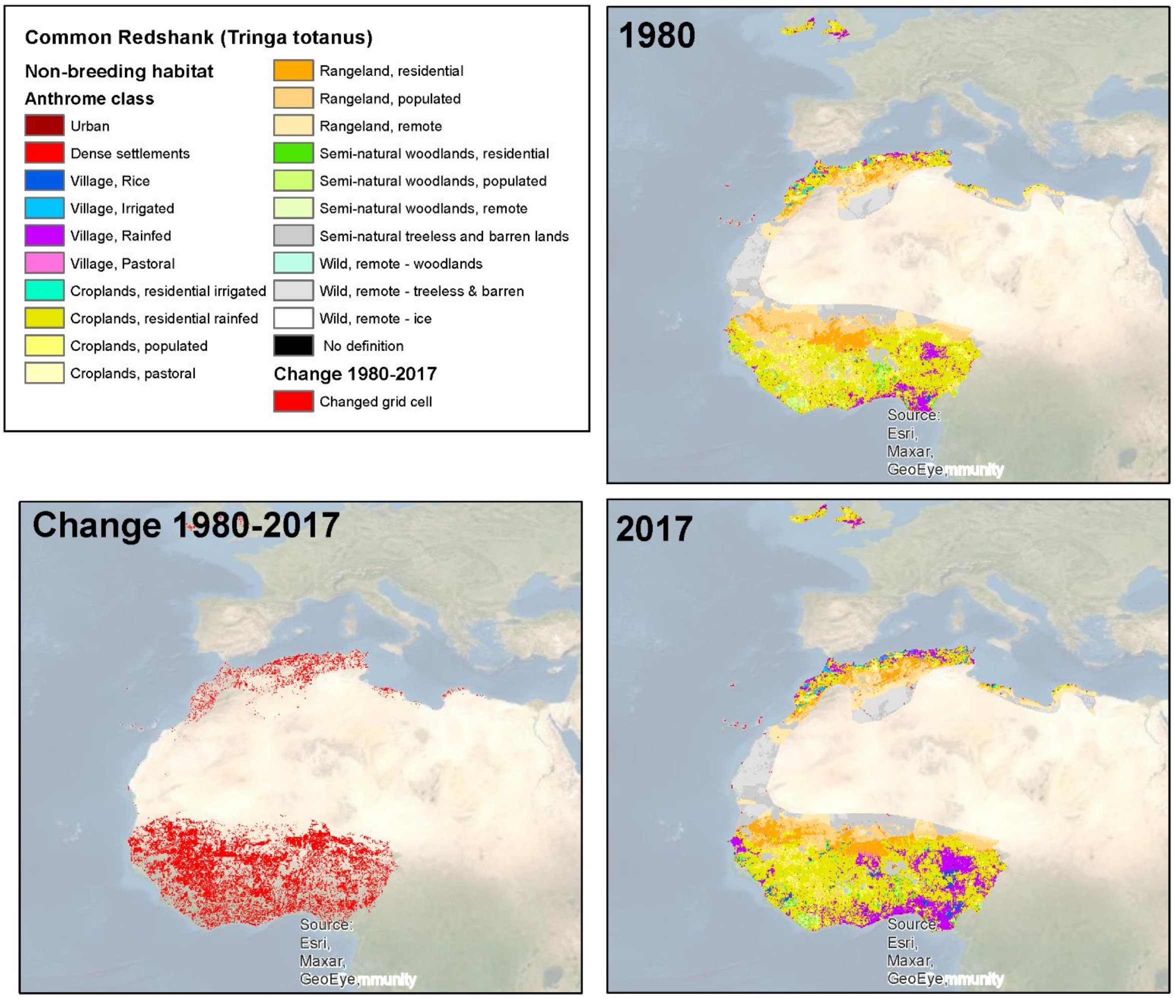
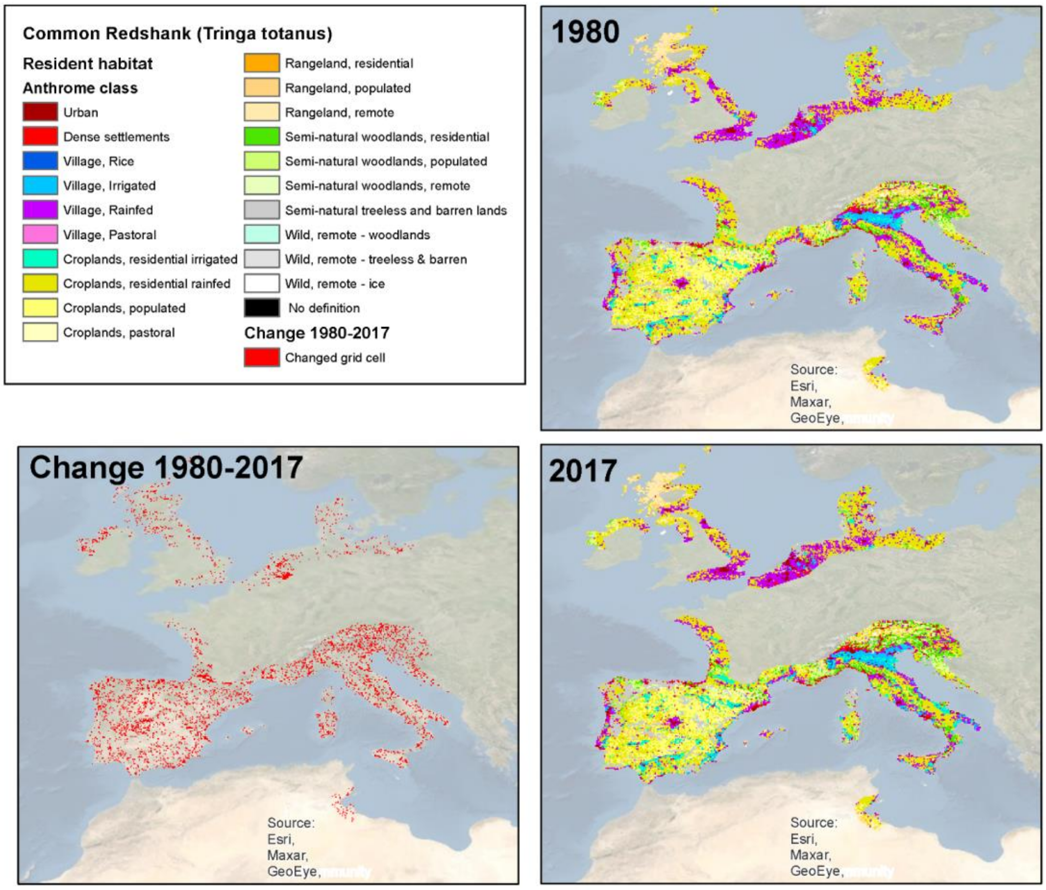


*Figure 20. Anthrome map Common Redshank Resident habitat (Klein Goldewijk et al., 2017; BirdLife International and Handbook of the Birds of the World, 2020)*



# Appendix C. Land cover changes

## C.I Tables

*Table 12. Land Cover changes Black-tailed Godwit all habitats*

| | Breeding | | | Non-breeding | | | Resident | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1992 | 2015 | Change (in %) | 1992 | 2015 | Change (in %) | 1992 | 2015 | Change (in %) |
| 10 Cropland, rainfed | 11.252 | 10.775 | -4.24 | 41.591 | 42.791 | 2.89 | 0.032 | 0.027 | -14.06 |
| 11 Herbaceous cover | 35.616 | 34.704 | -2.56 | 21.823 | 22.744 | 4.22 | 0.712 | 0.673 | -5.36 |
| 12 Tree or shrub cover | 0.409 | 0.403 | -1.58 | 1.218 | 1.241 | 1.91 | 0.001 | 0.001 | -3.62 |
| 20 Cropland, irrigated or post-flooding | 0.000 | 0.000 | 47 | 3.216 | 3.408 | 5.99 | | | |
| 30 Mosaic cropland (>50%) | 6.352 | 6.008 | -5.42 | 9.476 | 9.683 | 2.19 | 0.038 | 0.036 | -5.8 |
| 40 Mosaic natural vegetation | 1.501 | 0.621 | -58.66 | 7.888 | 7.376 | -6.49 | 0.029 | 0.020 | -28.9 |
| 50 Tree cover, broadleaved, | | | | 2.487 | 2.336 | -6.05 | | | |
| 60 Tree cover, broadleaved, | 5.167 | 5.148 | -0.38 | 3.155 | 3.059 | -3.05 | 0.011 | 0.011 | 3.22 |
| 61 Tree cover, broadleaved, | 0.003 | 0.004 | 12.43 | 0.004 | 0.004 | -1.41 | 0.000 | 0.000 | 0 |
| 62 Tree cover, broadleaved, | | | | 3.826 | 3.901 | 1.97 | | | |
| 70 Tree cover, needleleaved, | 18.528 | 18.376 | -0.82 | 0.760 | 0.743 | -2.24 | 0.028 | 0.024 | -15.3 |
| 71 Tree cover, needleleaved, | | | | | | | | | |
| 80 Tree cover, needleleaved, | 0.002 | 0.002 | 4.18 | 0.000 | 0.001 | 39.9 | | | |
| 90 Tree cover, mixed leaf type | 4.023 | 4.273 | 6.23 | 0.092 | 0.094 | 2.57 | 0.006 | 0.006 | 3.62 |
| 100 Mosaic tree and shrub (>50%) | 3.685 | 4.284 | 16.23 | 2.901 | 3.290 | 13.41 | 0.016 | 0.017 | 4.71 |
| 110 Mosaic herbaceous cover (>50%) | 1.711 | 1.810 | 5.8 | 0.685 | 0.526 | -23.18 | 0.007 | 0.007 | -1.04 |
| 120 Shrubland | 0.019 | 0.022 | 17 | 6.593 | 5.530 | -16.13 | | | |
| 121 Evergreen shrubland | | | | | | | | | |
| 122 Deciduous shrubland | 0.029 | 0.030 | 1.87 | 0.357 | 0.342 | -4.26 | | | |
| 130 Grassland | 11.437 | 11.516 | 0.7 | 23.080 | 22.555 | -2.27 | 0.298 | 0.284 | -4.65 |
| 140 Lichens and mosses | 1.407 | 1.407 | -0.01 | 5.668 | 4.639 | -18.16 | | | |
| 150 Sparse vegetation (<15%) | 4.212 | 4.162 | -1.2 | 0.082 | 0.083 | 1.27 | 0.002 | 0.002 | -1.46 |
| 152 Sparse shrub (<15%) | 0.022 | 0.024 | 5.46 | 8.025 | 8.238 | 2.65 | | | |
| 153 Sparse herbaceous cover (<15%) | | | | | | | | | |
| 160 Tree cover, flooded, fresh or brakish water | 0.000 | 0.000 | -10.58 | 0.014 | 0.014 | -1.99 | | | |
| 170 Tree cover, flooded, saline water | | | | 1.674 | 1.666 | -0.51 | | | |
| 180 Shrub or herbaceous cover, flooded | 2.985 | 2.479 | -16.95 | 1.621 | 1.643 | 1.35 | 0.041 | 0.038 | -6.17 |
| 190 Urban areas | 2.564 | 4.882 | 90.38 | 1.227 | 2.359 | 92.24 | 0.111 | 0.182 | 64.86 |
| 200 Bare areas | 2.036 | 2.022 | -0.69 | 14.570 | 13.822 | -5.14 | 0.004 | 0.003 | -20.52 |
| 201 Consolidated bare areas | 0.085 | 0.086 | 0.87 | 0.200 | 0.207 | 3.74 | 0.000 | 0.000 | -7.41 |
| 202 Unconsolidated bare areas | 0.002 | 0.002 | 0.67 | 0.009 | 0.009 | -1.83 | 0.000 | 0.000 | -10.39 |
| 210 Water bodies | 2.323 | 2.333 | 0.43 | 1.963 | 1.901 | -3.16 | 0.040 | 0.041 | 4.11 |
| 220 Permanent snow and ice | 0.327 | 0.327 | 0 | | | | | | |

*Table 13. Land Cover changes Common Redshank all habitats*

| | Breeding | | | Non-breeding | | | Resident | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1992 | 2015 | Change (in %) | 1992 | 2015 | Change (in %) | 1992 | 2015 | Change (in %) |
| 10 Cropland, rainfed | 13.158 | 13.694 | 4.07 | 91.736 | 97.188 | 5.94271 | 14.197 | 14.079 | -0.8358 |
| 11 Herbaceous cover | 30.881 | 30.335 | -1.77 | 22.518 | 25.080 | 11.3734 | 39.545 | 39.373 | -0.4346 |
| 12 Tree or shrub cover | 0.297 | 0.295 | -0.47 | 0.004 | 0.007 | 77.4082 | 8.207 | 8.345 | 1.67979 |
| 20 Cropland, irrigated or post-flooding | 0.000 | 0.000 | 0 | 3.680 | 3.972 | 7.93499 | 3.393 | 3.393 | -0.0068 |
| 30 Mosaic cropland (>50%) | 5.836 | 5.644 | -3.29 | 23.175 | 24.578 | 6.05455 | 7.994 | 8.173 | 2.24095 |
| 40 Mosaic natural vegetation | 2.286 | 1.352 | -40.86 | 20.233 | 19.766 | -2.3075 | 8.651 | 7.529 | -12.964 |
| 50 Tree cover, broadleaved, | | | | 11.581 | 10.219 | -11.762 | | | |
| 60 Tree cover, broadleaved, | 12.019 | 12.147 | 1.07 | 2.346 | 3.034 | 29.3308 | 18.286 | 16.501 | -9.7588 |
| 61 Tree cover, broadleaved, | 0.005 | 0.007 | 20.39 | 0.006 | 0.006 | -2.9832 | 0.018 | 0.018 | 0.29718 |
| 62 Tree cover, broadleaved, | | | | 45.241 | 49.462 | 9.3292 | | | |
| 70 Tree cover, needleleaved, | 51.883 | 50.915 | -1.87 | 0.483 | 0.496 | 2.70766 | 16.417 | 15.172 | -7.5809 |
| 71 Tree cover, needleleaved, | | | | | | | 0.000 | 0.000 | -19.676 |
| 80 Tree cover, needleleaved, | 0.007 | 0.008 | 26.04 | 0.001 | 0.001 | 1.05422 | 0.065 | 0.062 | -5.1821 |
| 90 Tree cover, mixed leaf type | 5.968 | 6.037 | 1.16 | 0.000 | 0.000 | 0 | 3.188 | 3.228 | 1.23675 |
| 100 Mosaic tree and shrub (>50%) | 7.314 | 8.579 | 17.29 | 4.436 | 4.863 | 9.60769 | 12.875 | 14.469 | 12.3815 |
| 110 Mosaic herbaceous cover (>50%) | 11.074 | 11.852 | 7.03 | 1.005 | 0.658 | -34.497 | 2.710 | 2.683 | -1.0023 |
| 120 Shrubland | 0.039 | 0.060 | 55.15 | 41.591 | 30.665 | -26.27 | 3.330 | 3.482 | 4.58591 |
| 121 Evergreen shrubland | | | | | | | 0.000 | 0.000 | 0 |
| 122 Deciduous shrubland | 0.738 | 0.739 | 0.21 | 4.624 | 4.451 | -3.7306 | 0.021 | 0.021 | 2.09397 |
| 130 Grassland | 12.427 | 12.459 | 0.26 | 43.980 | 44.009 | 0.06621 | 19.478 | 19.804 | 1.67596 |
| 140 Lichens and mosses | 1.919 | 1.919 | 0 | | | | | | |
| 150 Sparse vegetation (<15%) | 18.290 | 17.411 | -4.8 | 17.235 | 16.529 | -4.094 | 2.080 | 1.638 | -21.242 |
| 152 Sparse shrub (<15%) | 0.225 | 0.224 | -0.62 | 0.160 | 0.166 | 3.27354 | | | |
| 153 Sparse herbaceous cover (<15%) | | | | 20.183 | 21.617 | 7.1031 | 0.799 | 0.777 | -2.8263 |
| 160 Tree cover, flooded, fresh or brakish water | 0.003 | 0.004 | 22.14 | 0.047 | 0.045 | -2.9794 | | | |
| 170 Tree cover, flooded, saline water | | | | 1.718 | 1.708 | -0.5499 | | 0.000 | |
| 180 Shrub or herbaceous cover, flooded | 10.482 | 9.194 | -12.29 | 1.258 | 1.187 | -5.6163 | 2.825 | 2.620 | -7.266 |
| 190 Urban areas | 2.508 | 4.551 | 81.44 | 0.883 | 1.932 | 118.836 | 2.768 | 5.544 | 100.288 |
| 200 Bare areas | 5.470 | 5.487 | 0.31 | 120.012 | 116.348 | -3.0525 | 2.802 | 2.674 | -4.563 |
| 201 Consolidated bare areas | 0.118 | 0.118 | 0.33 | 0.930 | 0.902 | -3.0548 | 0.459 | 0.491 | 6.94274 |
| 202 Unconsolidated bare areas | 0.001 | 0.001 | 5.47 | 0.107 | 0.107 | -0.1079 | 0.029 | 0.030 | 1.78632 |
| 210 Water bodies | 8.485 | 8.400 | -1 | 2.868 | 3.045 | 6.16927 | 2.025 | 2.056 | 1.51737 |
| 220 Permanent snow and ice | 1.324 | 1.324 | 0 | | | | 0.077 | 0.077 | 0 |

## C.II Maps

Figure 21. Black-tailed Godwit Breeding habitat Land cover changes *(ESA, 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

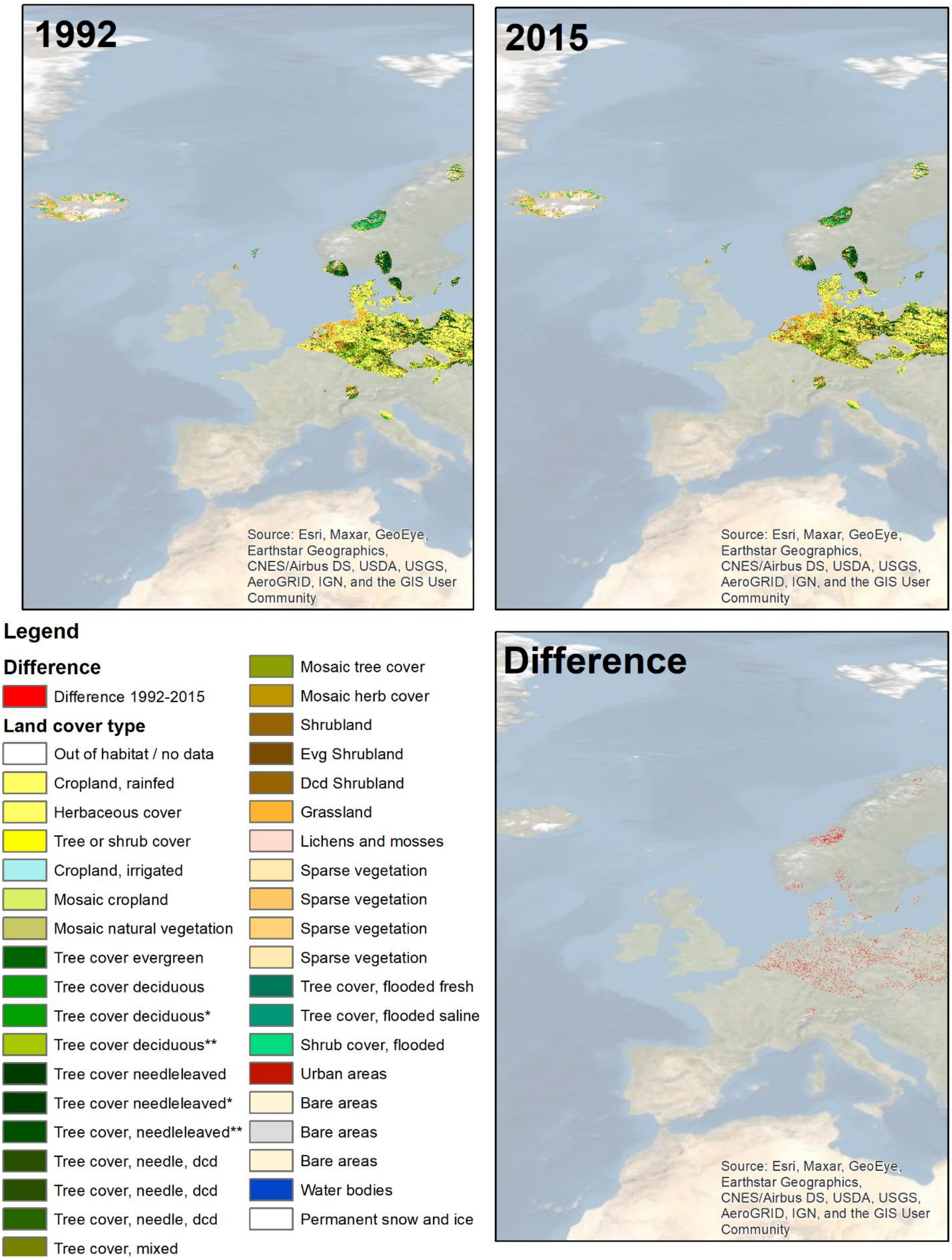


*Figure 22. Black-tailed Godwit Non-breeding habitat Land cover changes (ESA, 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

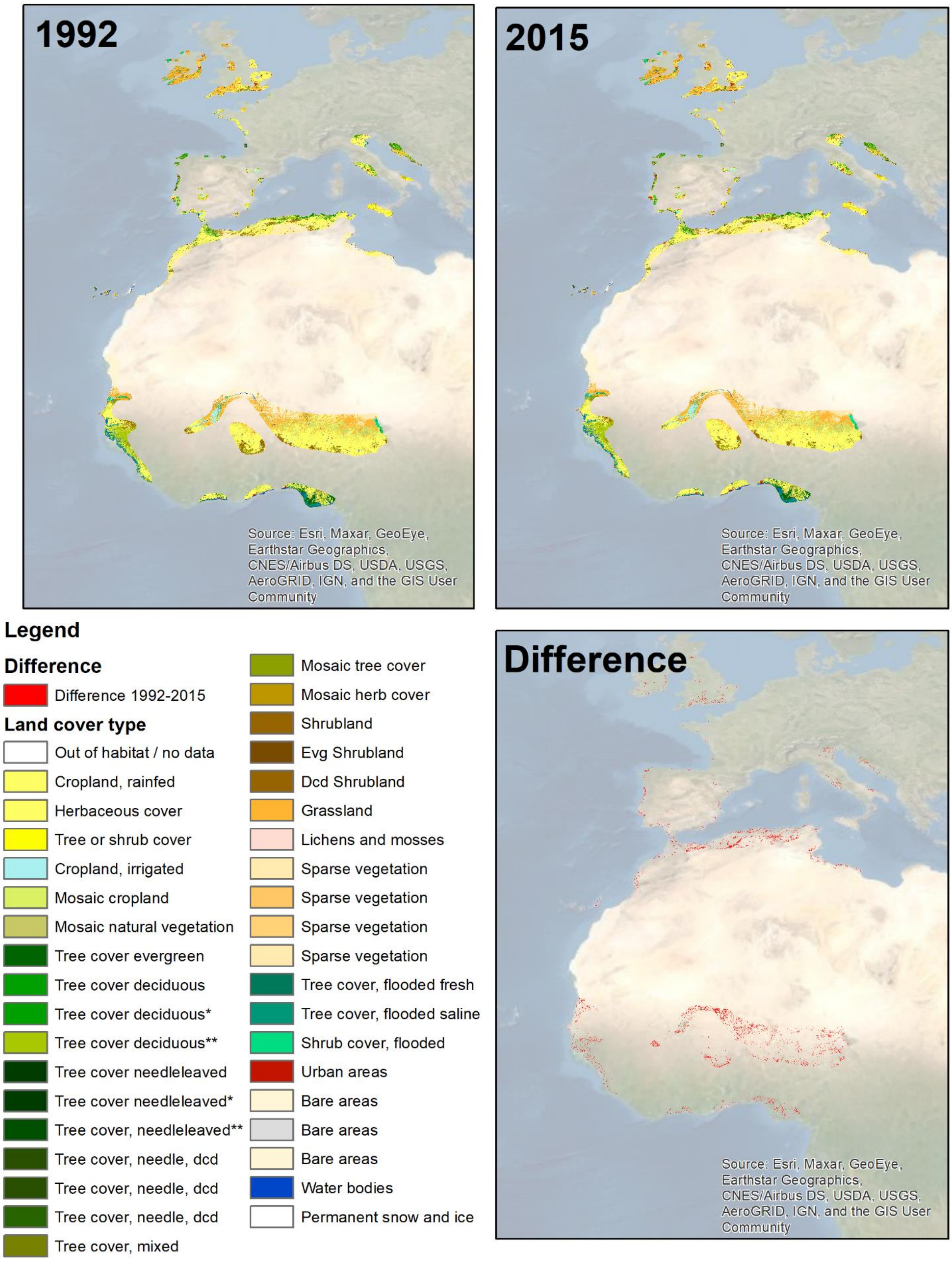


*Figure 23. Black-tailed Godwit Resident habitat Land cover changes (ESA, 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

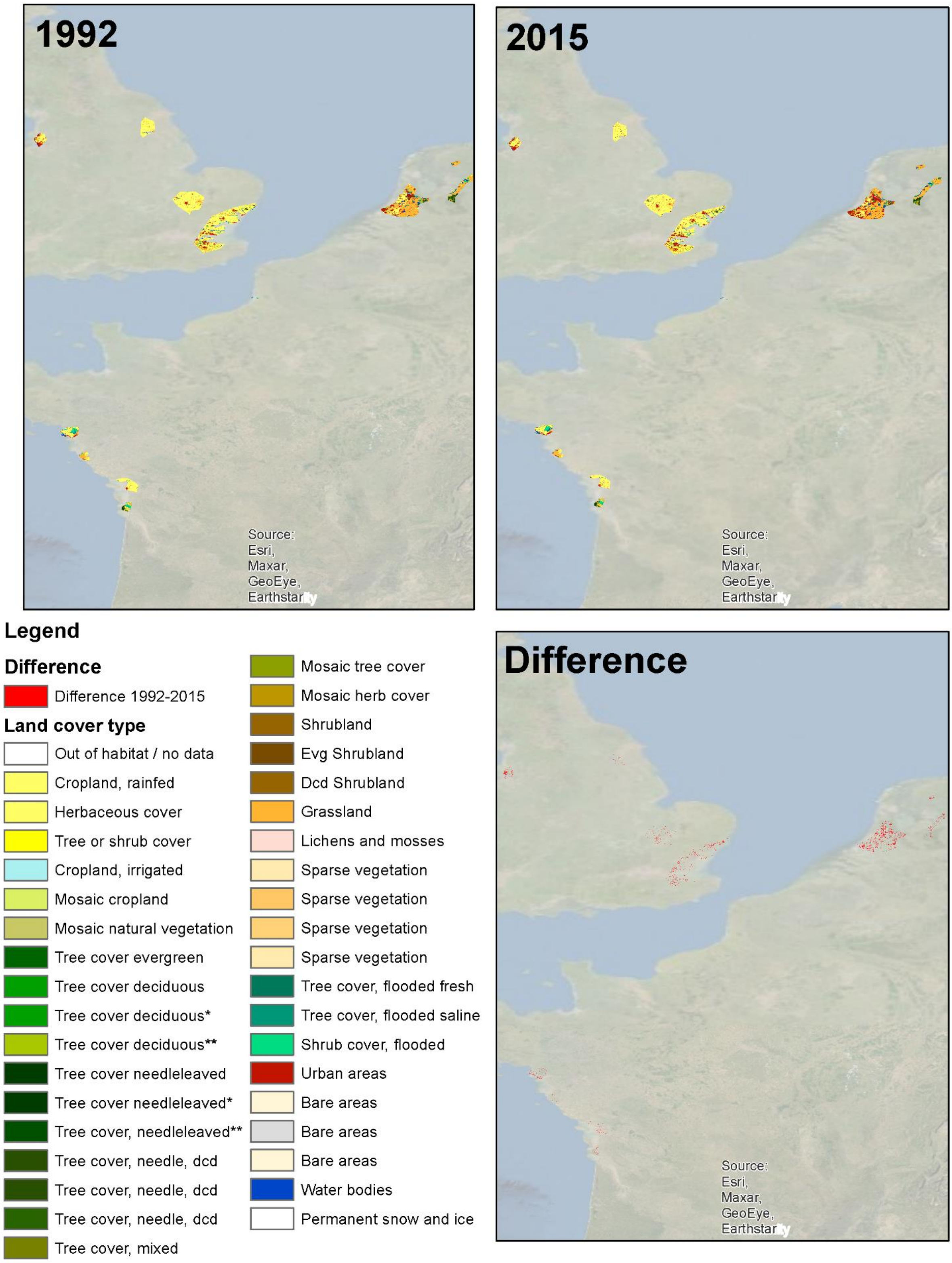


*Figure 24. Common Redshank Breeding habitat Land cover changes (ESA, 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

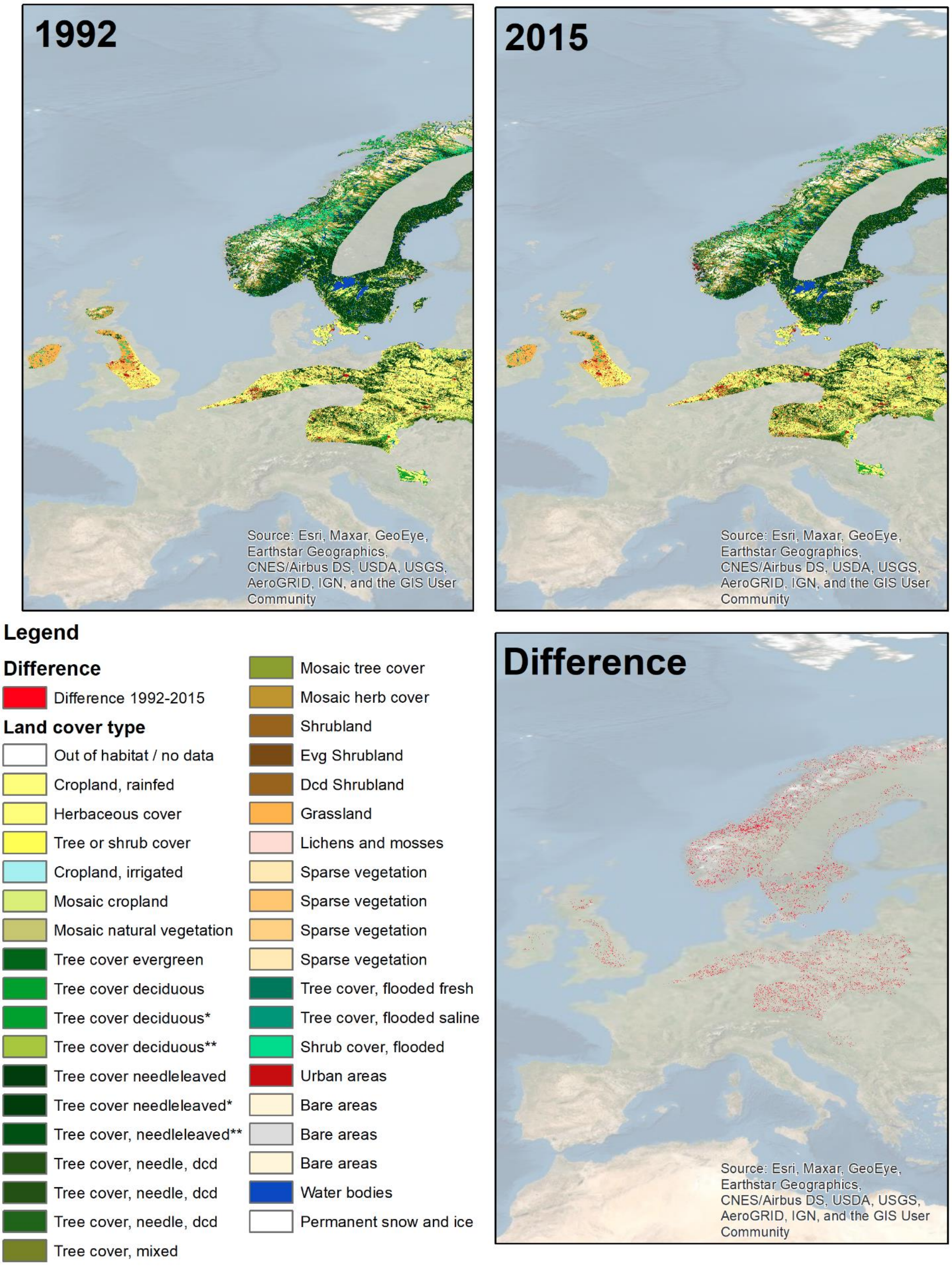


*Figure 25. Common Redshank Non-breeding habitat Land cover changes (ESA, 2017; BirdLife International and Handbook of the Birds of the World, 2020)*

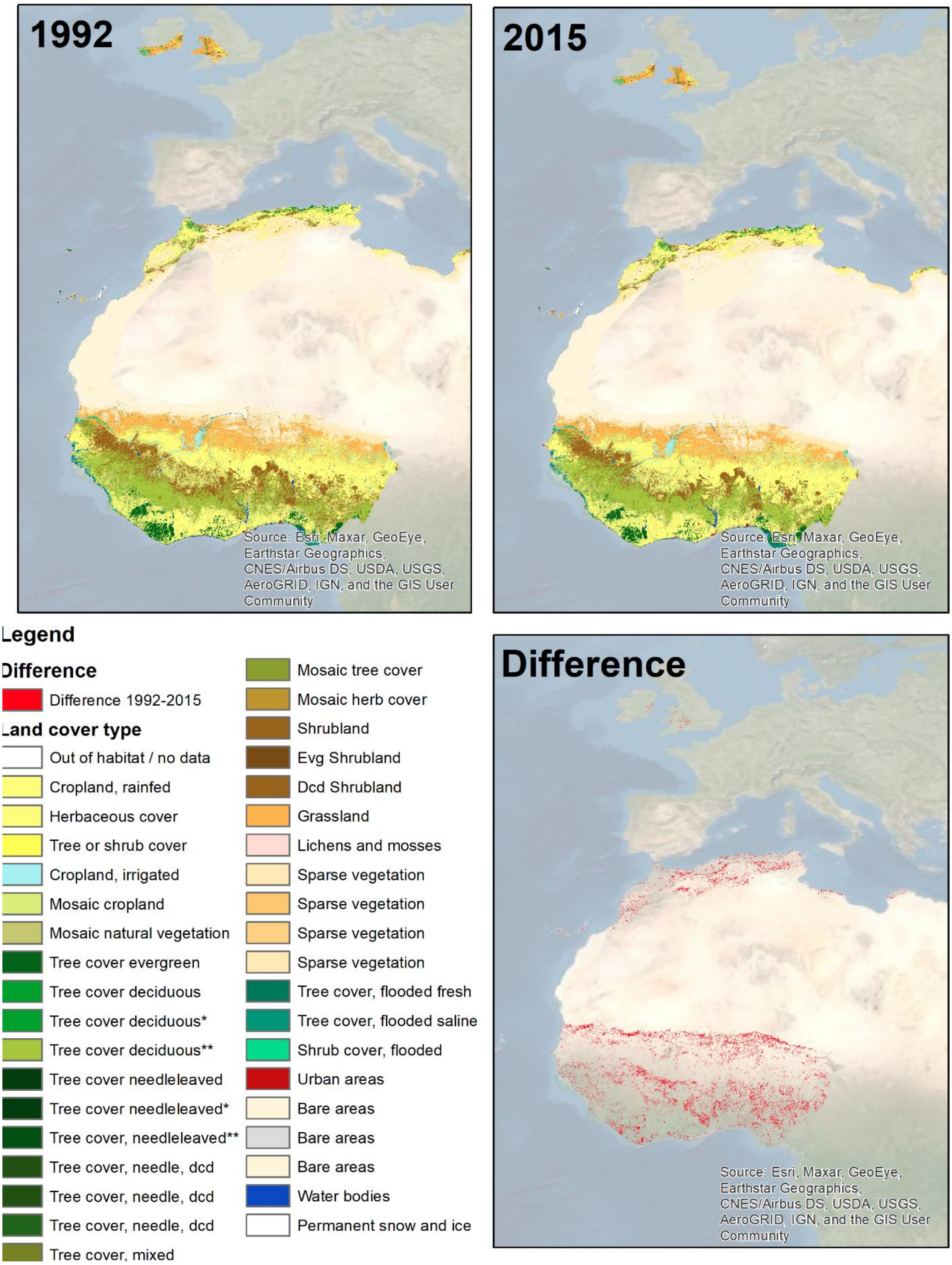


*Figure 26. Common Redshank Resident habitat Land cover changes (adapted from ESA, 2017; BirdLife International and Handbook of the Birds of the World, 2020)*